Accelerator Operations and Upgrade Plans

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U.S. DEPARTMENT OF ENERGY

Fermilab

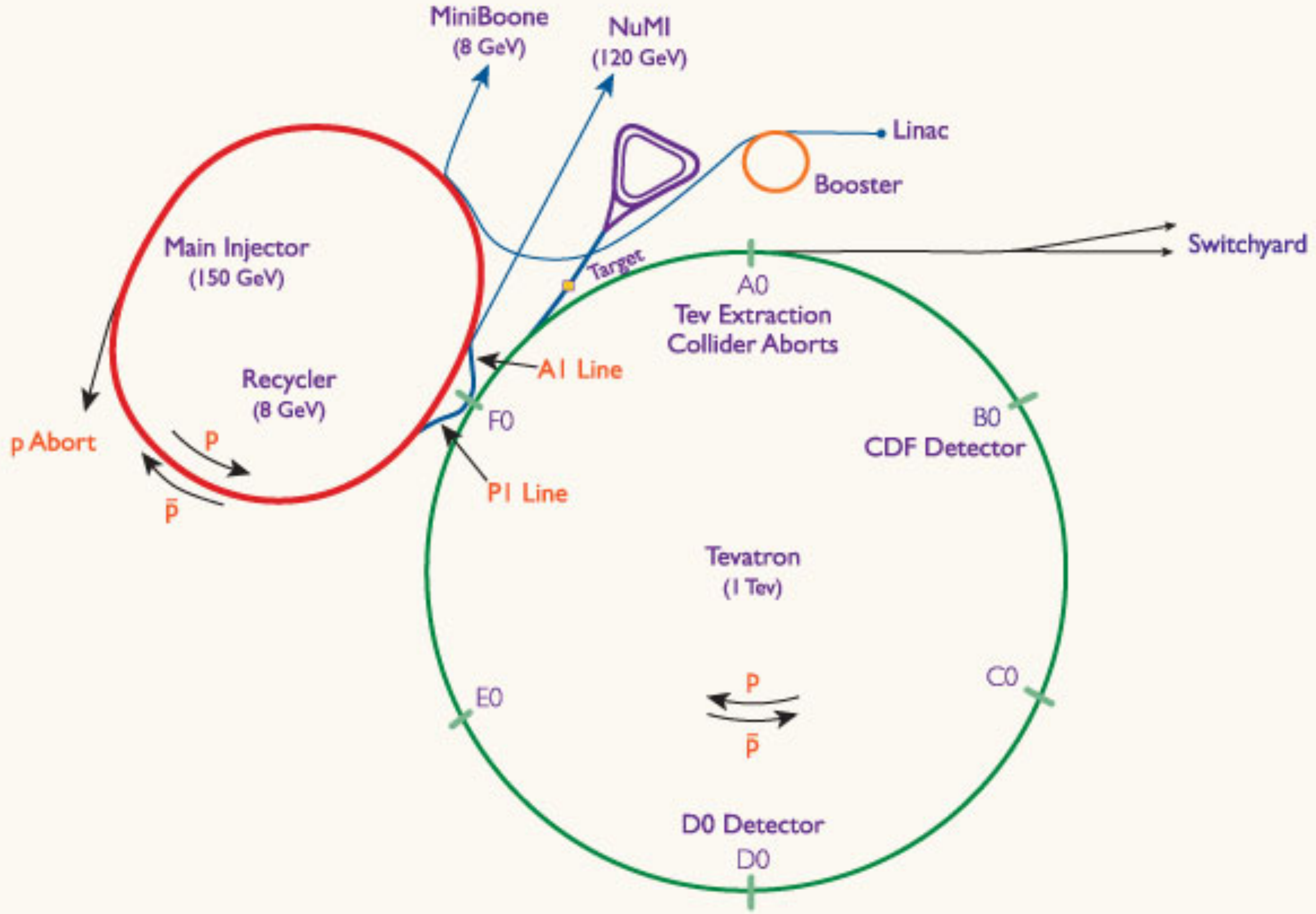
Overview

- Collider Performance
  - Tevatron Studies
- Neutrino Performance
- Proton Improvement Plan (PIP)
- NOvA

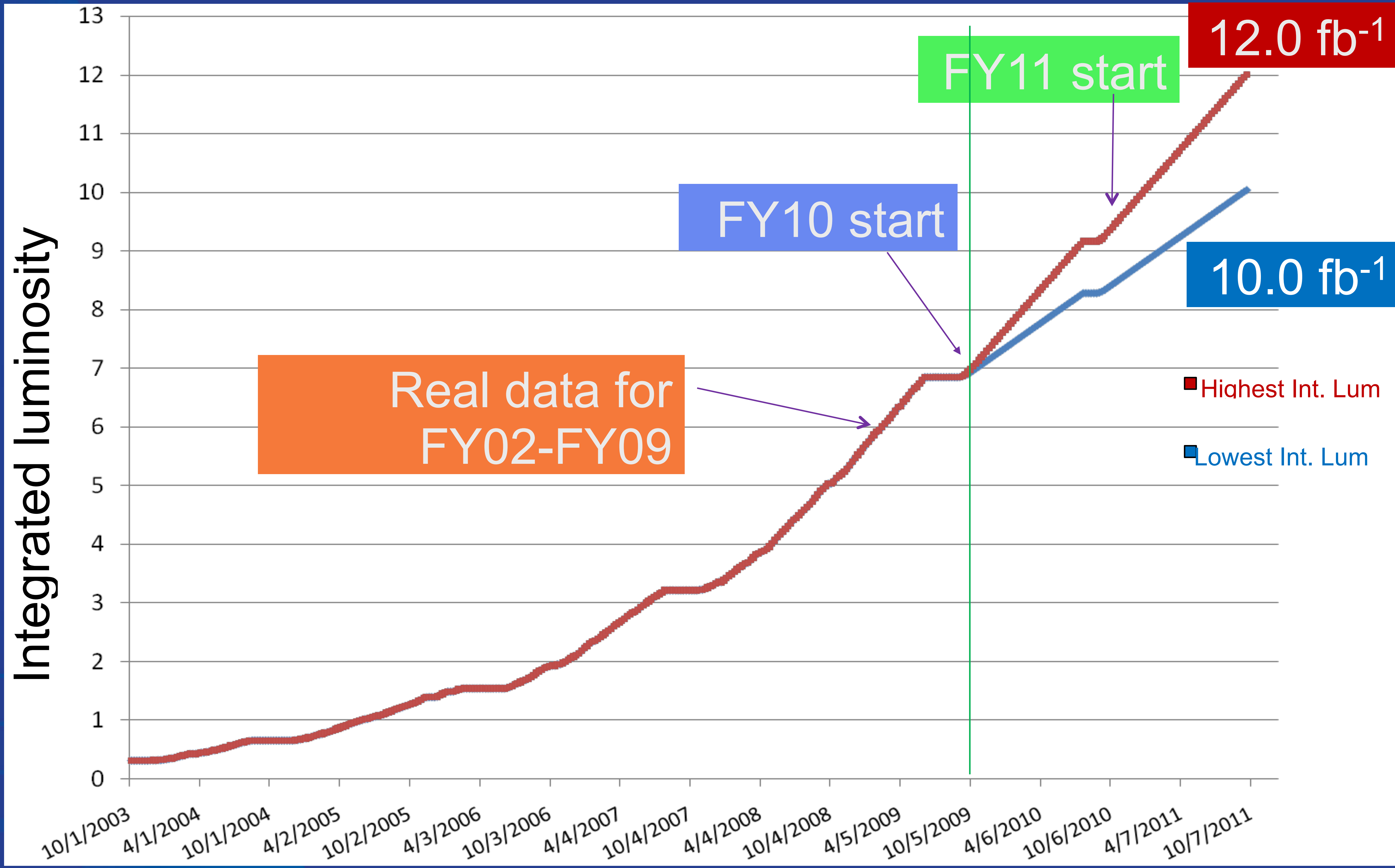
The Fermilab Accelerator Complex

- The Fermilab Accelerator Complex is made up of a chain of accelerators to accelerator protons, produce antiprotons and to produce neutrinos for use in the Collider and Fixed Target programs
    1) Cockcroft-Walton and pre-accelerator – 0 to 750 keV
    2) Linear Accelerator (Linac) – 0.75 MeV - 400 MeV
    3) Booster Synchrotron 400 MeV - 8 GeV
    4) Main Injector Synchrotron 8 GeV - 150 GeV
    5) Tevatron Synchrotron – 150 GeV - 980 GeV
    6) Antiproton Debuncher – 8 GeV
    7) Antiproton Accumulator – 8 GeV
    8) Anitiproton Recycler – 8 GeV
    9) Pelletron (electrons at 4.8 MeV)

Fermilab Accelerator Complex



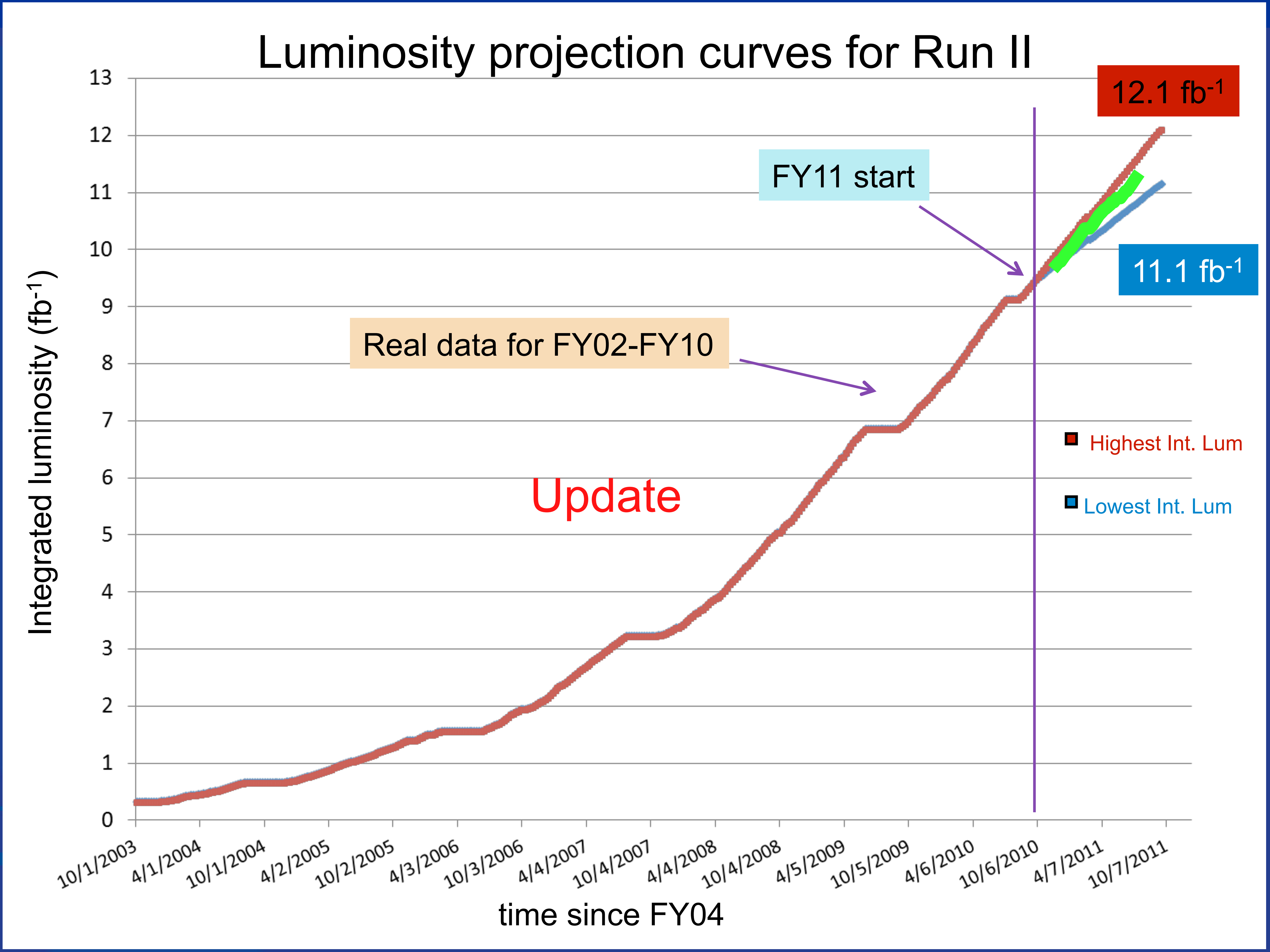
Luminosity Projection Curves for Run II



time since FY04

Projection Inputs

- The model predicts weekly integrated luminosity on the basis of 16 input parameters
- The inputs were selected in most cases by looking at the current performance of the machine
- The FY11 weekly projections were increased to 34 pb^{-1} for “minimum” and 53 pb^{-1} for “maximum”
- The “maximum” and “minimum” luminosity projections assume, as always, 100 and 120 HEP hours per week, respectively



Luminosity projection curves for Run II
Integrated luminosity (fb-1)
time since FY04
12.1 fb-1
11.1 fb-1
FY11 start
Real data for FY02-FY10
Update
Highest Int. Lum
Lowest Int. Lum
0
1
2
3
4
5
6
7
8
9
10
11
12
13
10/1/2003
4/1/2004
10/1/2004
4/2/2005
10/2/2005
4/3/2006
10/3/2006
4/4/2007
10/4/2007
4/4/2008
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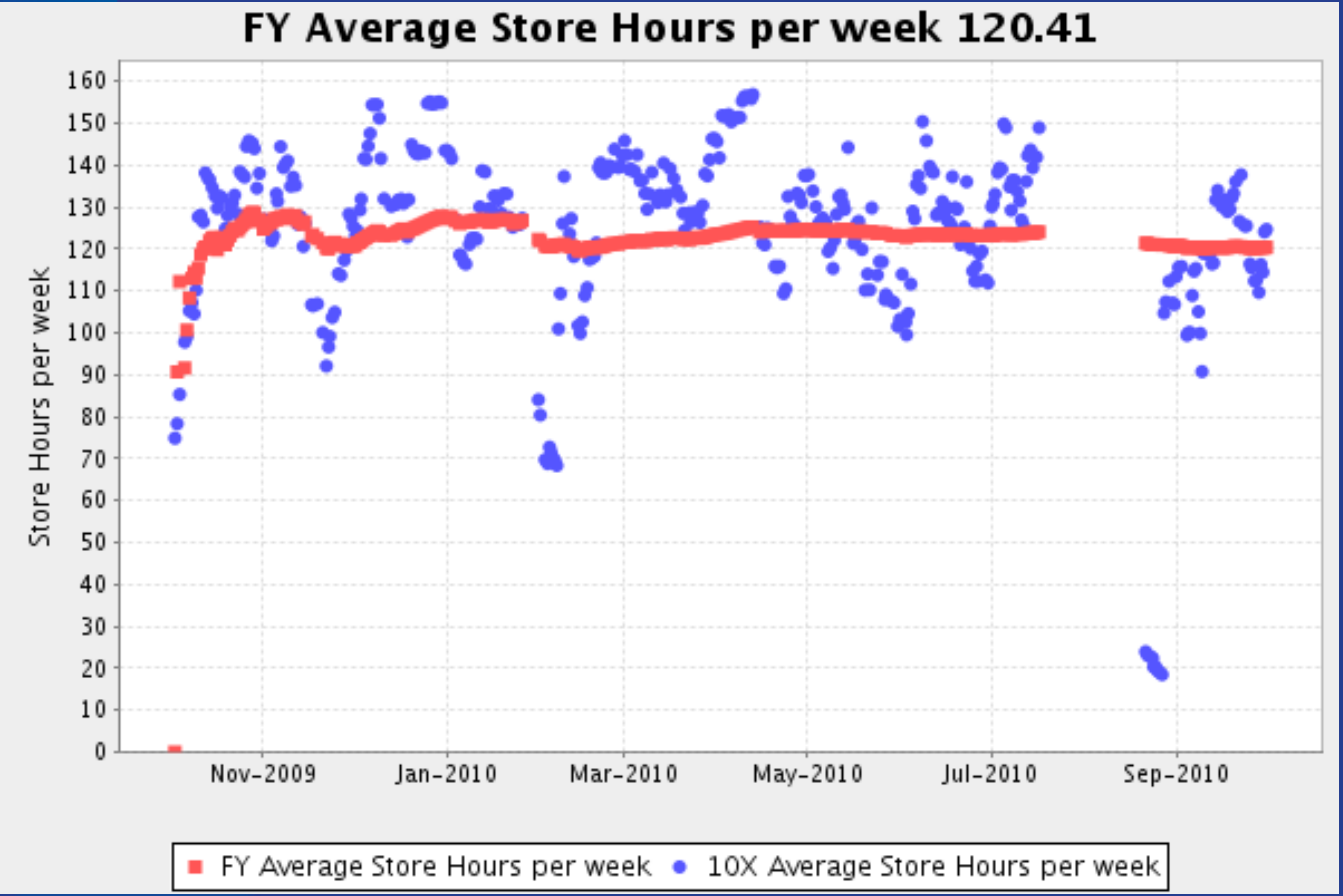
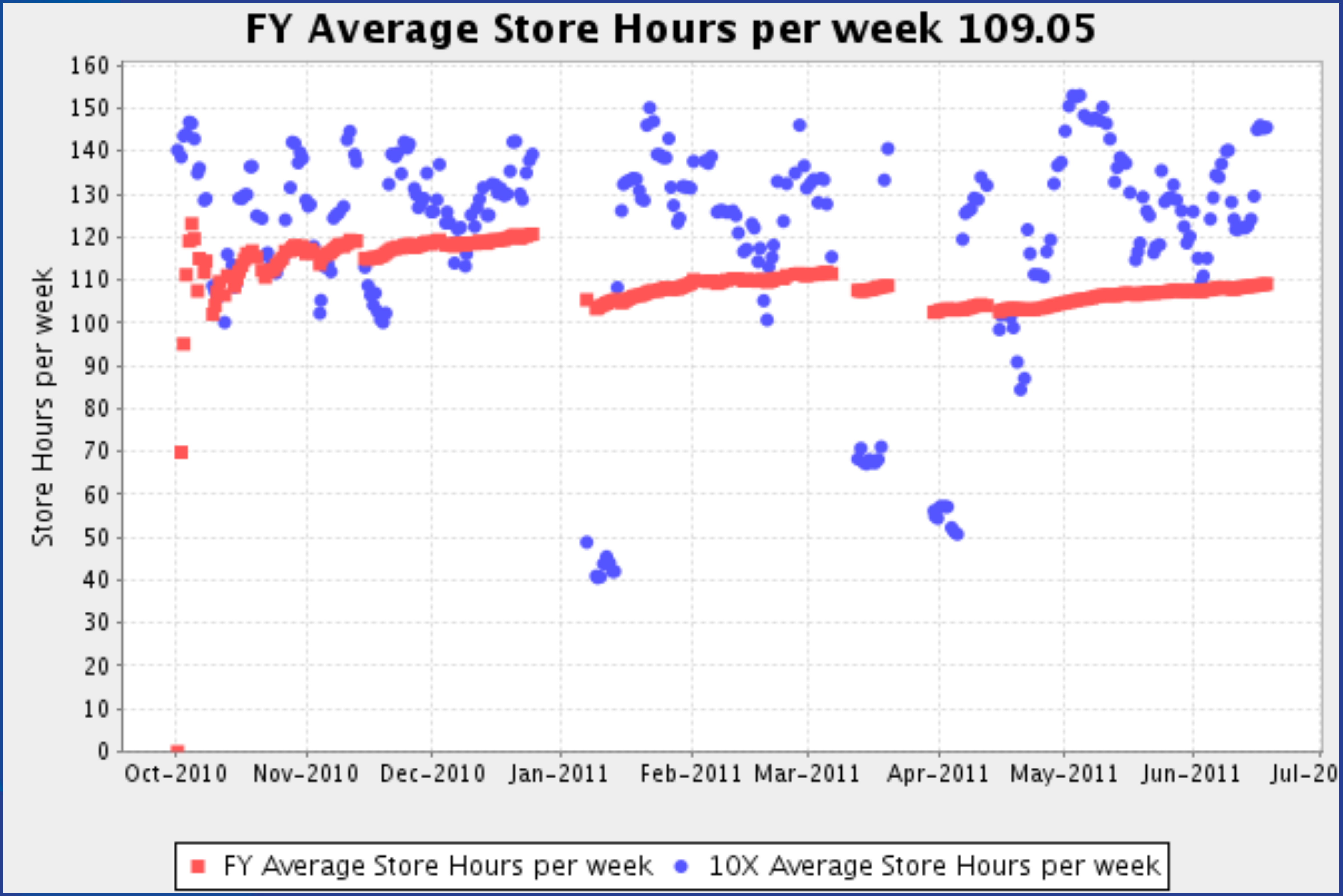
4/5/2009
10/5/2009
4/6/2010
10/6/2010
4/7/2011
10/7/2011

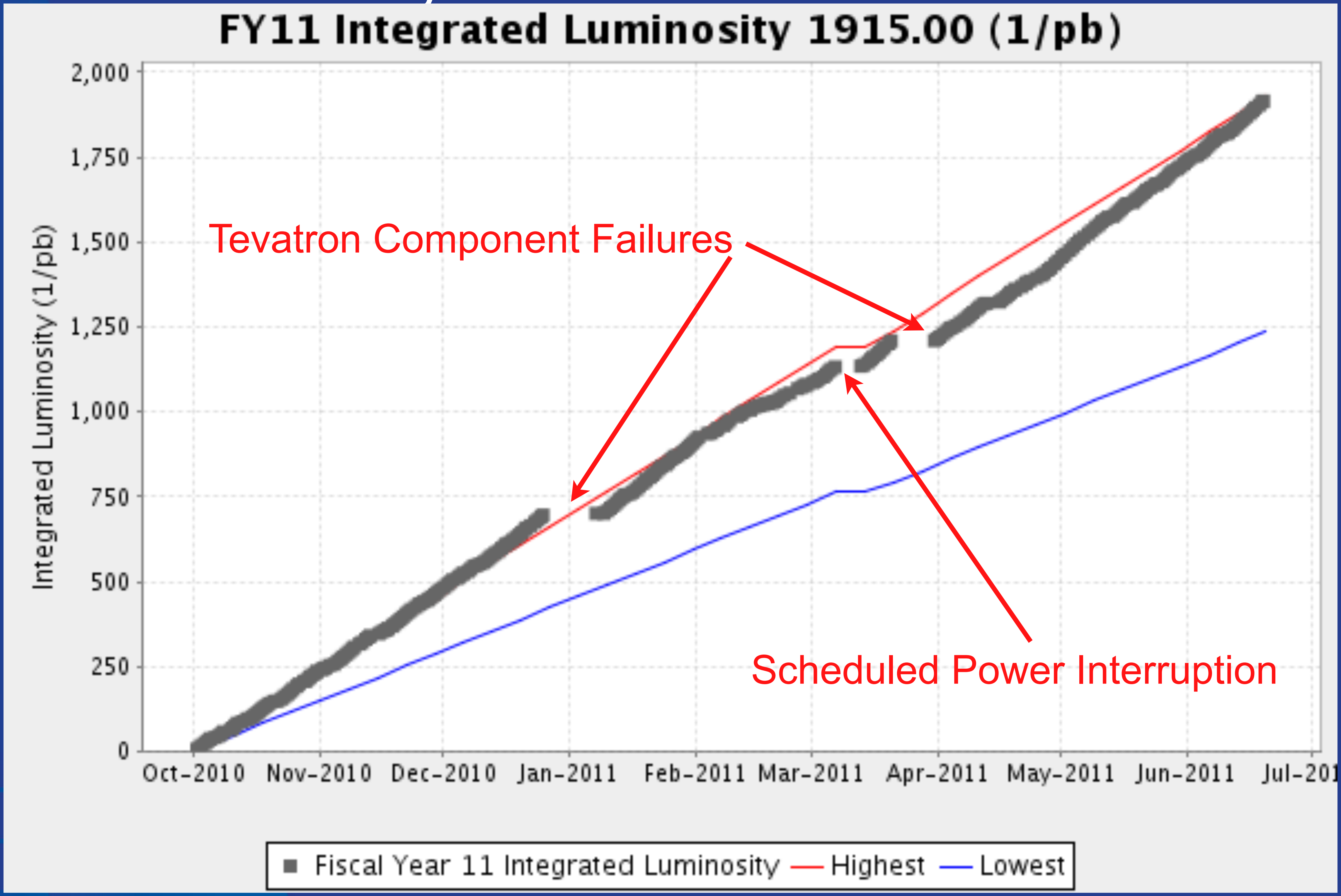
Store Hours 2010



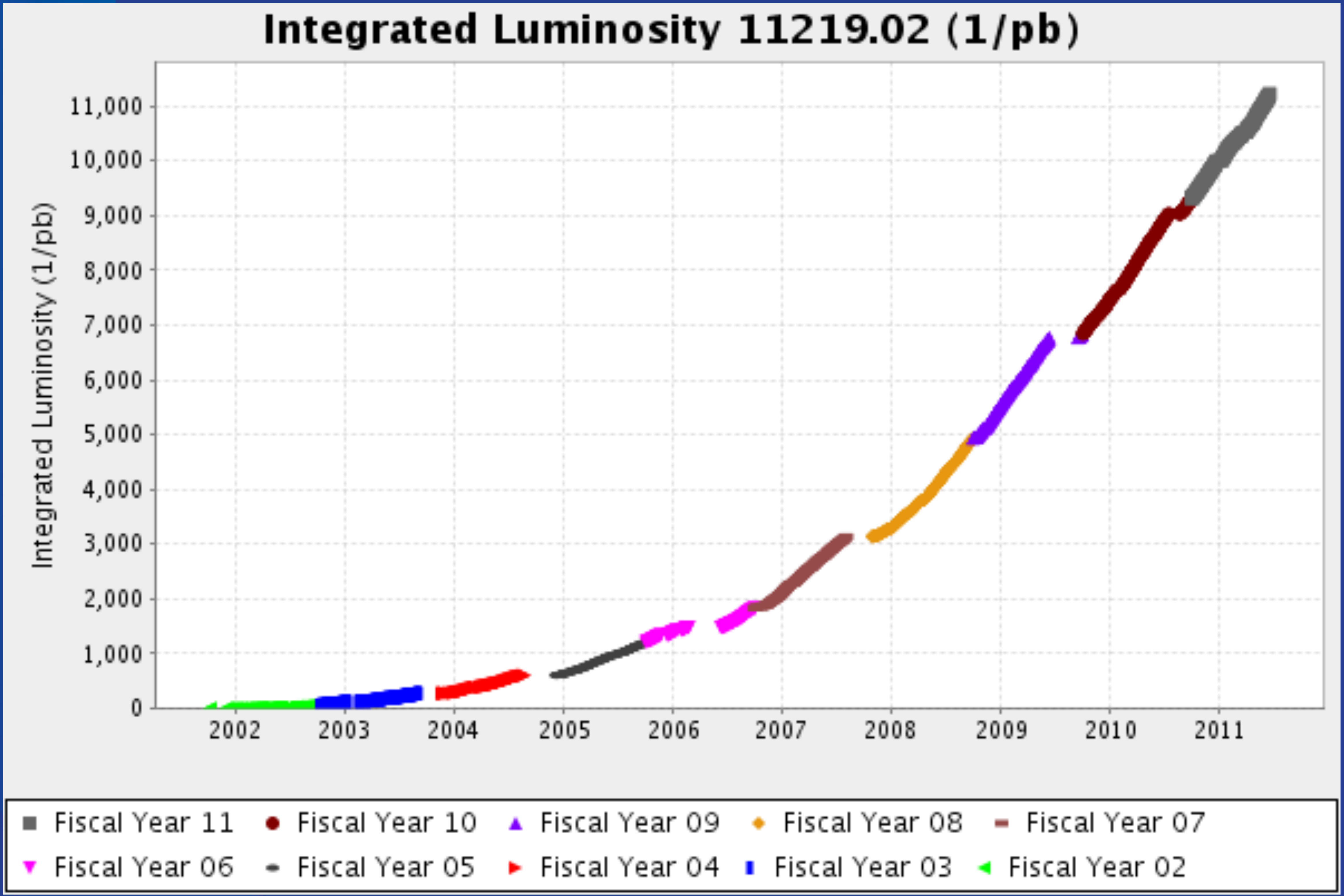
Store Hours 2011



Luminosity Detail



Total Integrated Luminosity



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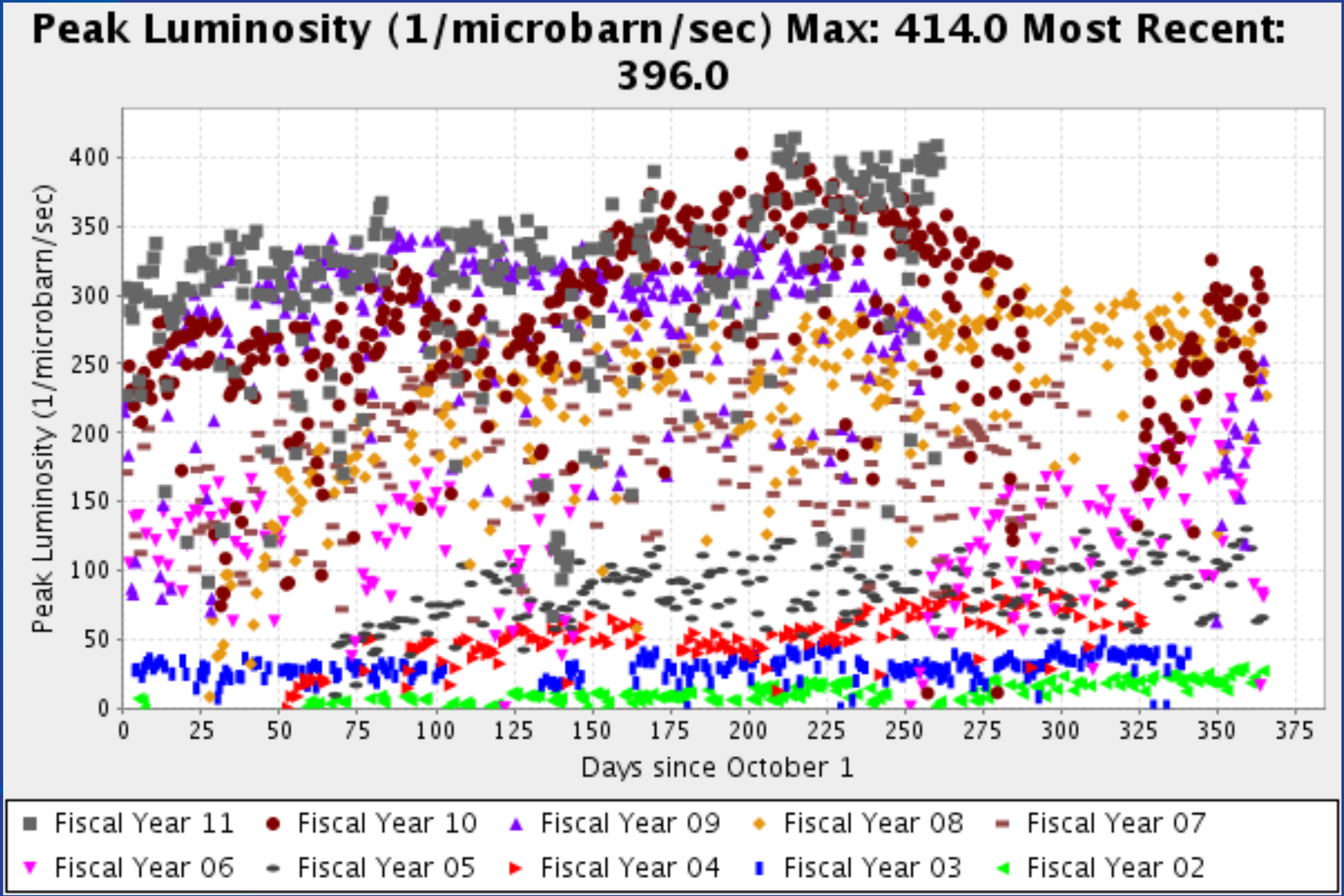
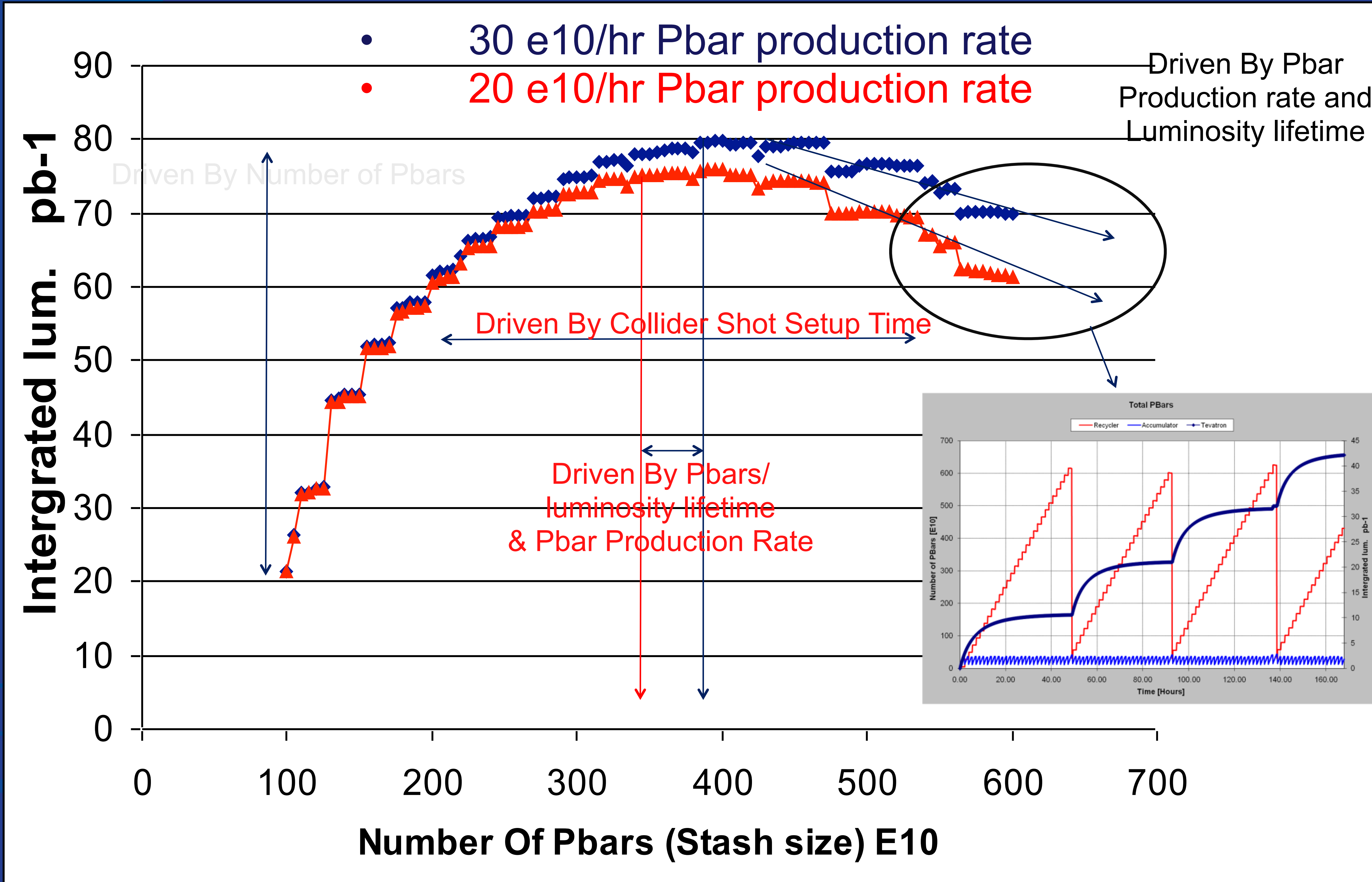
Initial Luminosity Optimization



Optimizing the Model



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Accelerator Studies at the Tevatron

- FNAL, CERN, BNL scientists pursuing topics of general interest and relevant for LHC machine upgrades *(collimation + beam-beam)*
  - Scheduling dedicated study periods, also being opportunistic when possible

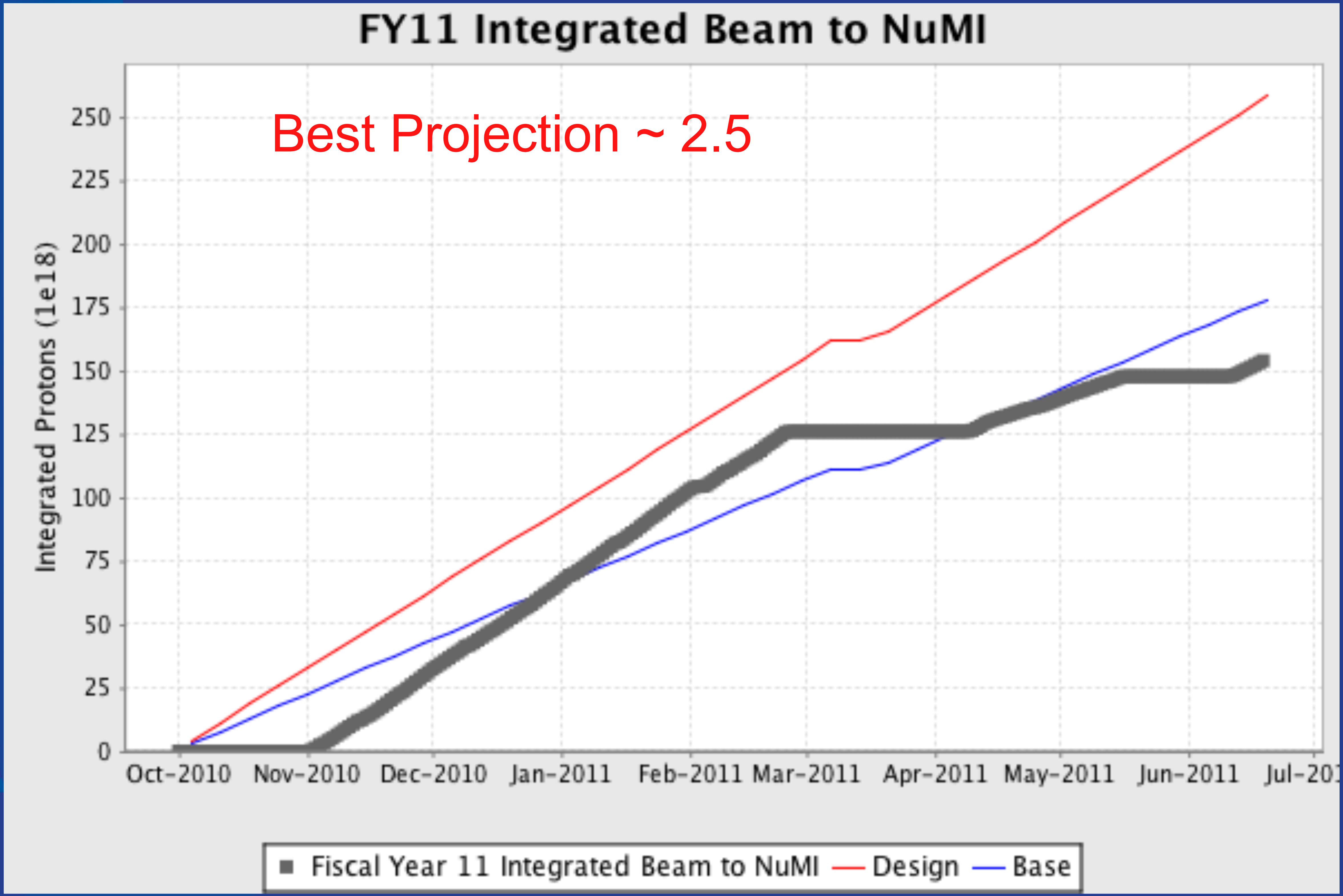
- Recently conducted crystal collimator studies (26 hrs over 2 weeks)
  - Test new crystal designs and instrumentation at end of colliding beam stores
  - Visitors from CERN and INFN (part of T-980 Collaboration)

- Hollow electron beam collimation
  - Completed 13 hrs of planned dedicated studies (~50% of proposed plan)

- Planning beam-beam studies during 2 week block at end of August
  - Mainly 3×3 colliding beam stores + AC dipole studies: ~35 hrs total time
  - Expect visitors from CERN and BNL

- Other shorter studies to be completed during June-August

NuMI Beam Performance



NuMI Target History

target	1st POT	last POT	weeks operation	Integrated POT	max beam power	max POT/spill	reason taken out of service
NT01	5/1/05	8/13/06	67	1.60E+20	270 kw	3.00E+13	drive stuck in high energy position
NT02	9/11/06	6/12/09	144	6.10E+20	340 kw	4.00E+13	graphite deteriorating, 10%-15% fewer nu/POT at peak
NT03	9/11/09	7/12/10	44	3.10E+20	375 kw	4.40E+13	break at ceramic tube-holder (probably water leak -> explosion)
NT04	8/22/10	9/17/10	4	2.00E+19	375 kw	4.30E+13	water leak -> explosion (blew off beryllium window)
NT05	10/29/10	2/24/11	17	1.30E+20	337 kw	4.00E+13	water leak -> eventual external water leak (water turnaround fell off)
NT06	4/7/11	5/16/11	6	2.00E+19	305 kw	3.50E+13	water leak -> eventual external water leak

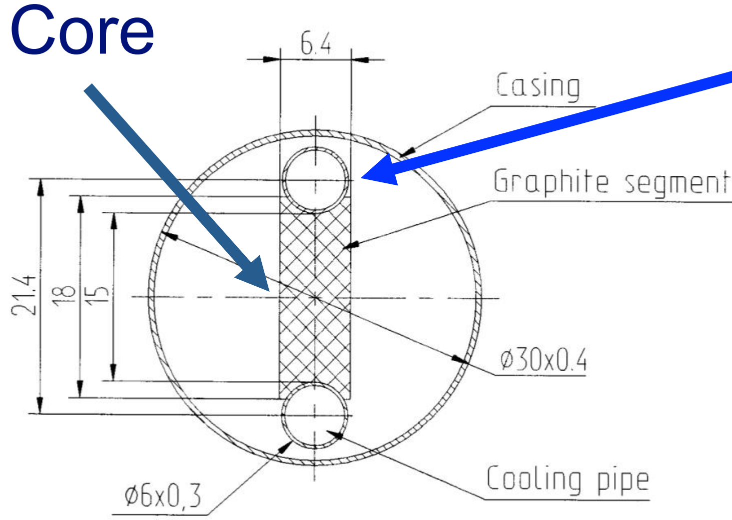
NUMI MINOS target

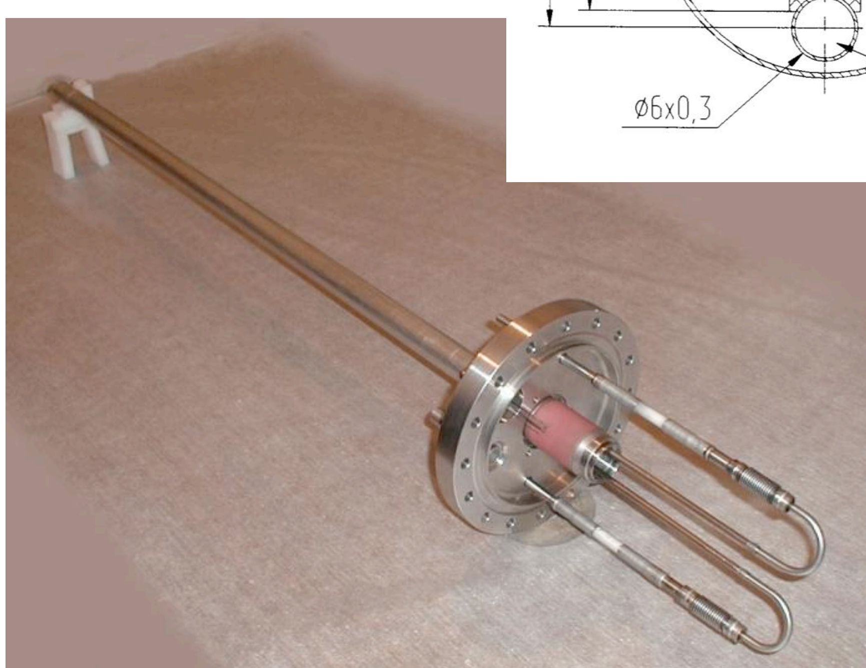
Designed with and constructed by IHEP Protvino Beams Group

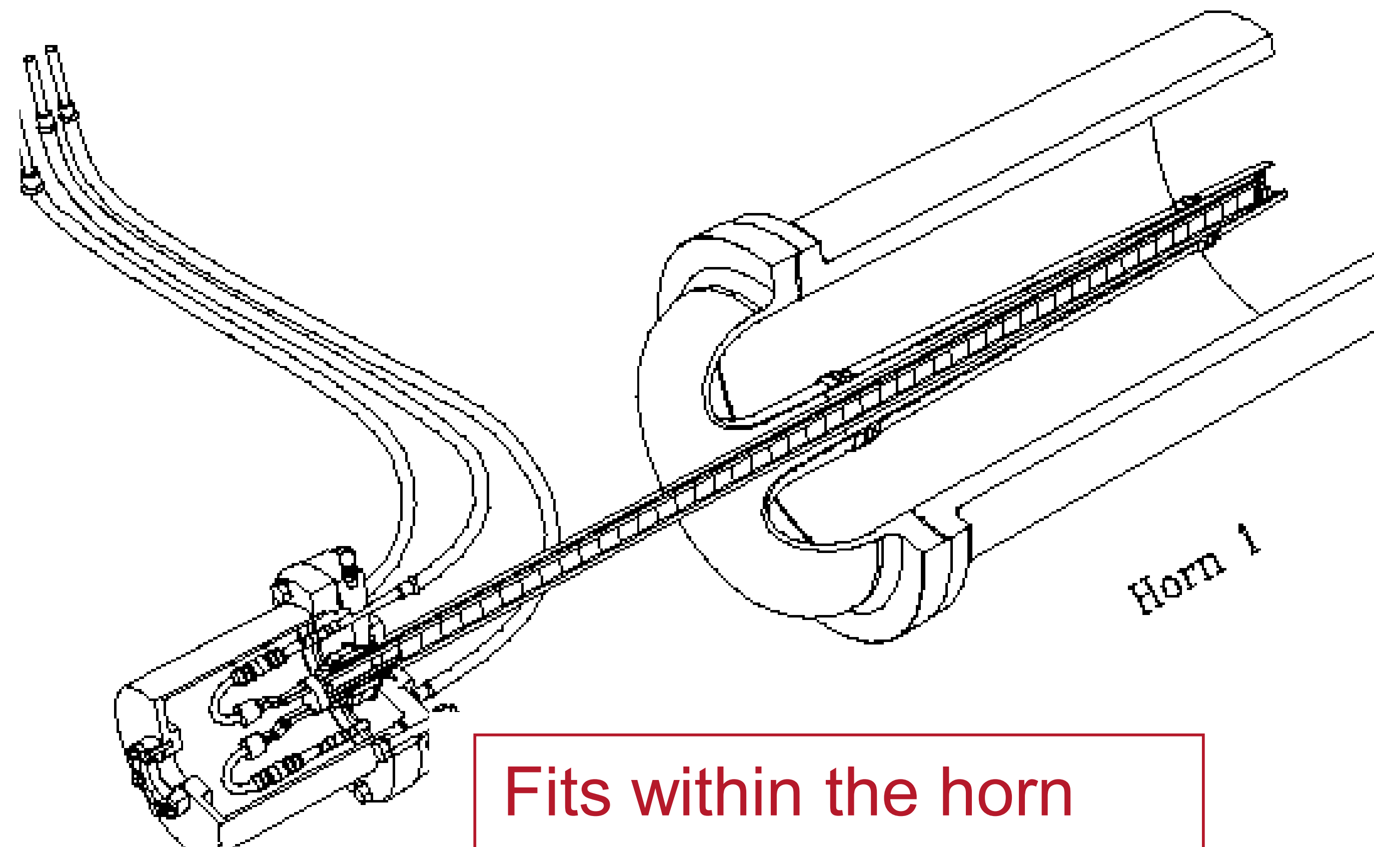
2 int. length long; narrow so pions get out sides without re-interacting

Graphite Fin Core
6.4 mm wide

Water cooling tube

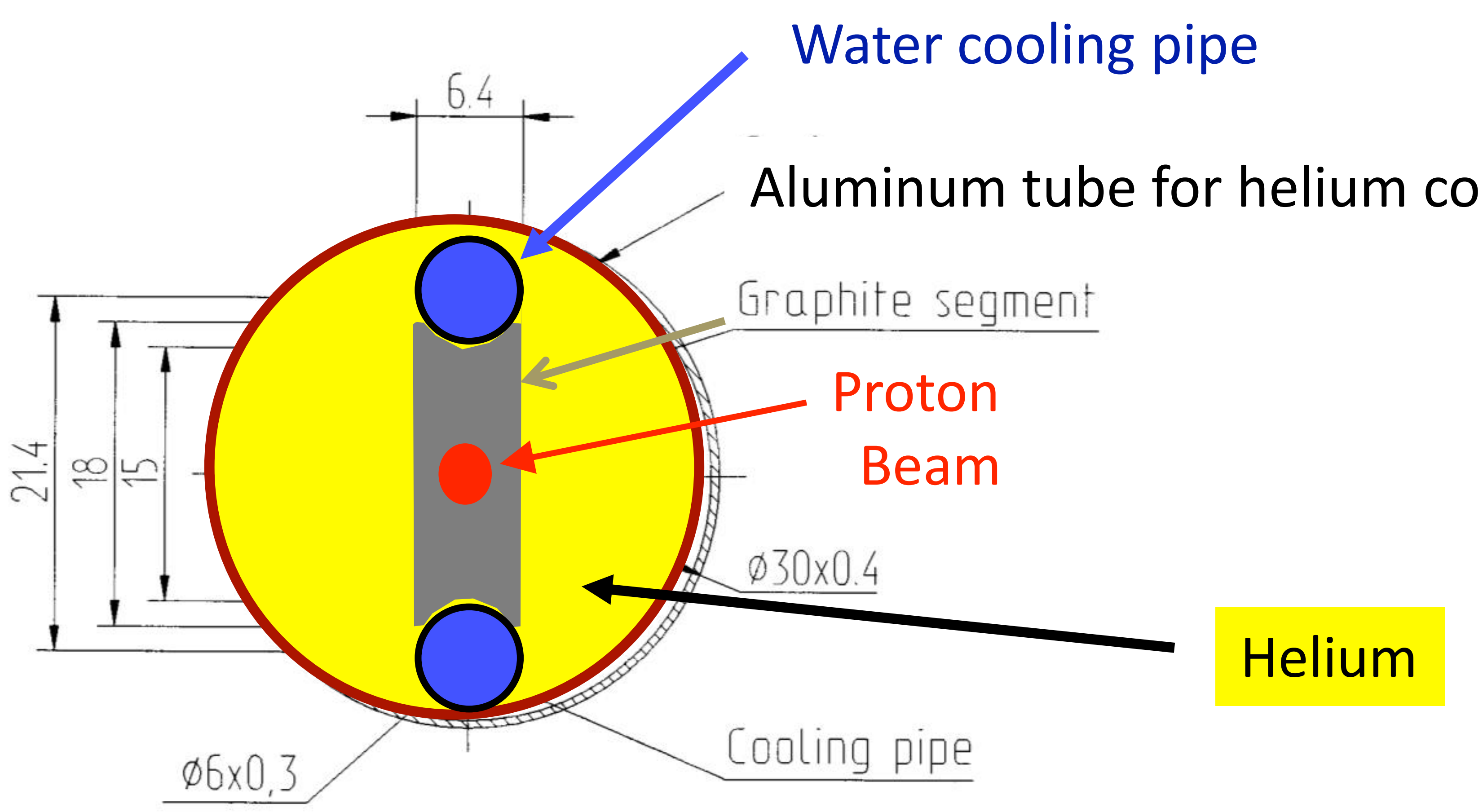






Fits within the horn without touching.

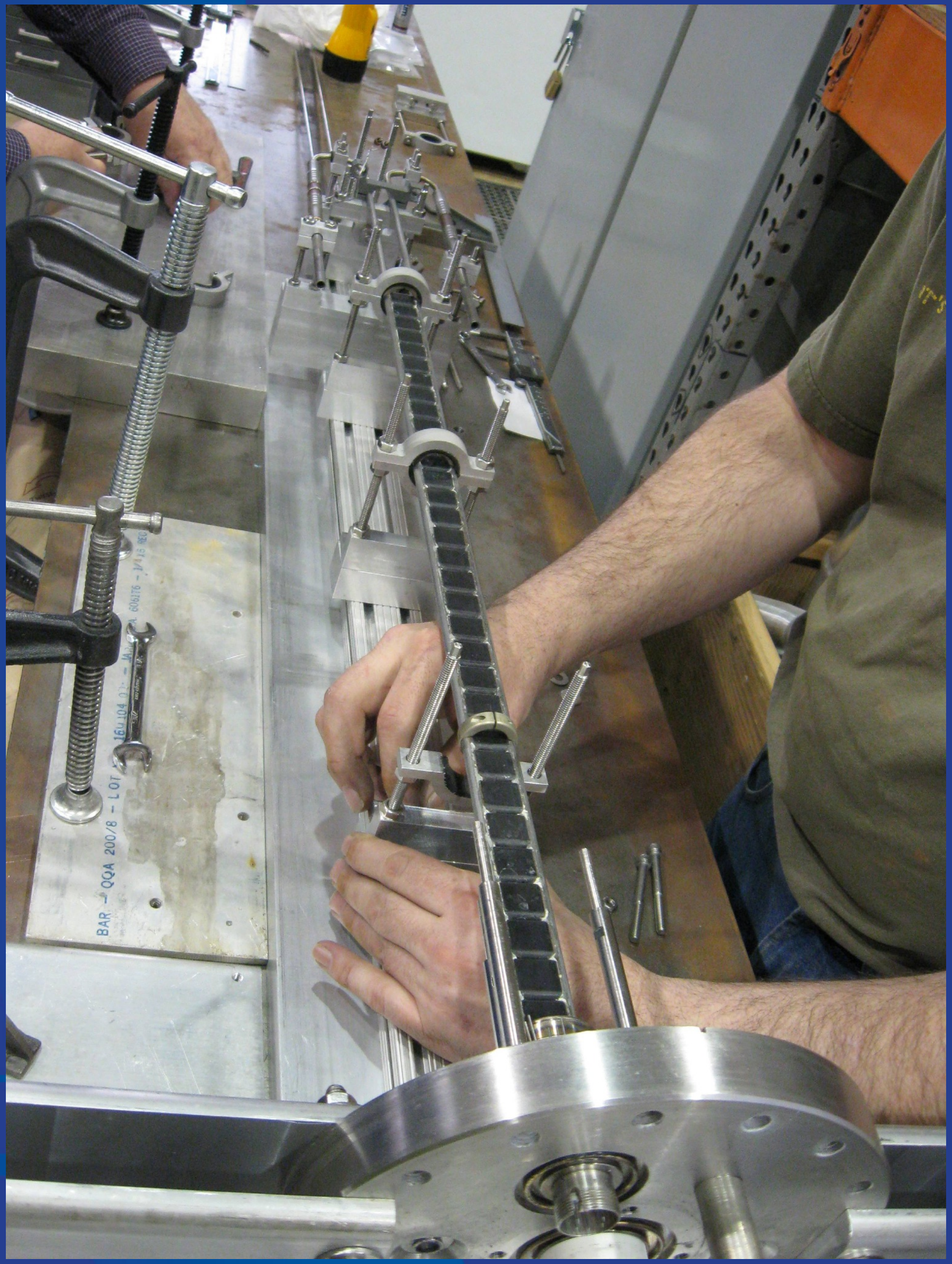
NUMI LE Target

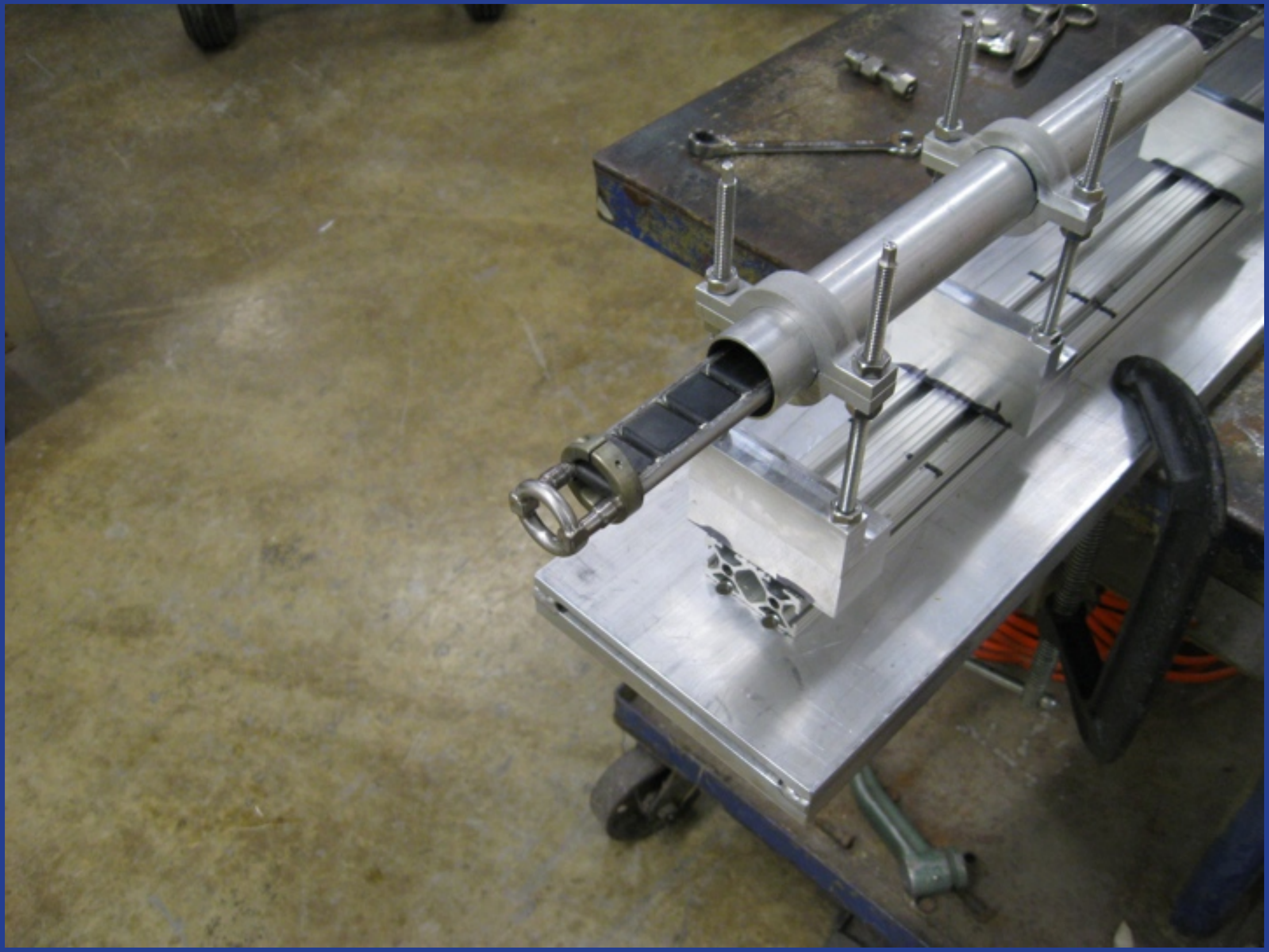


MINOS LE target

All units mm

NuMI Target





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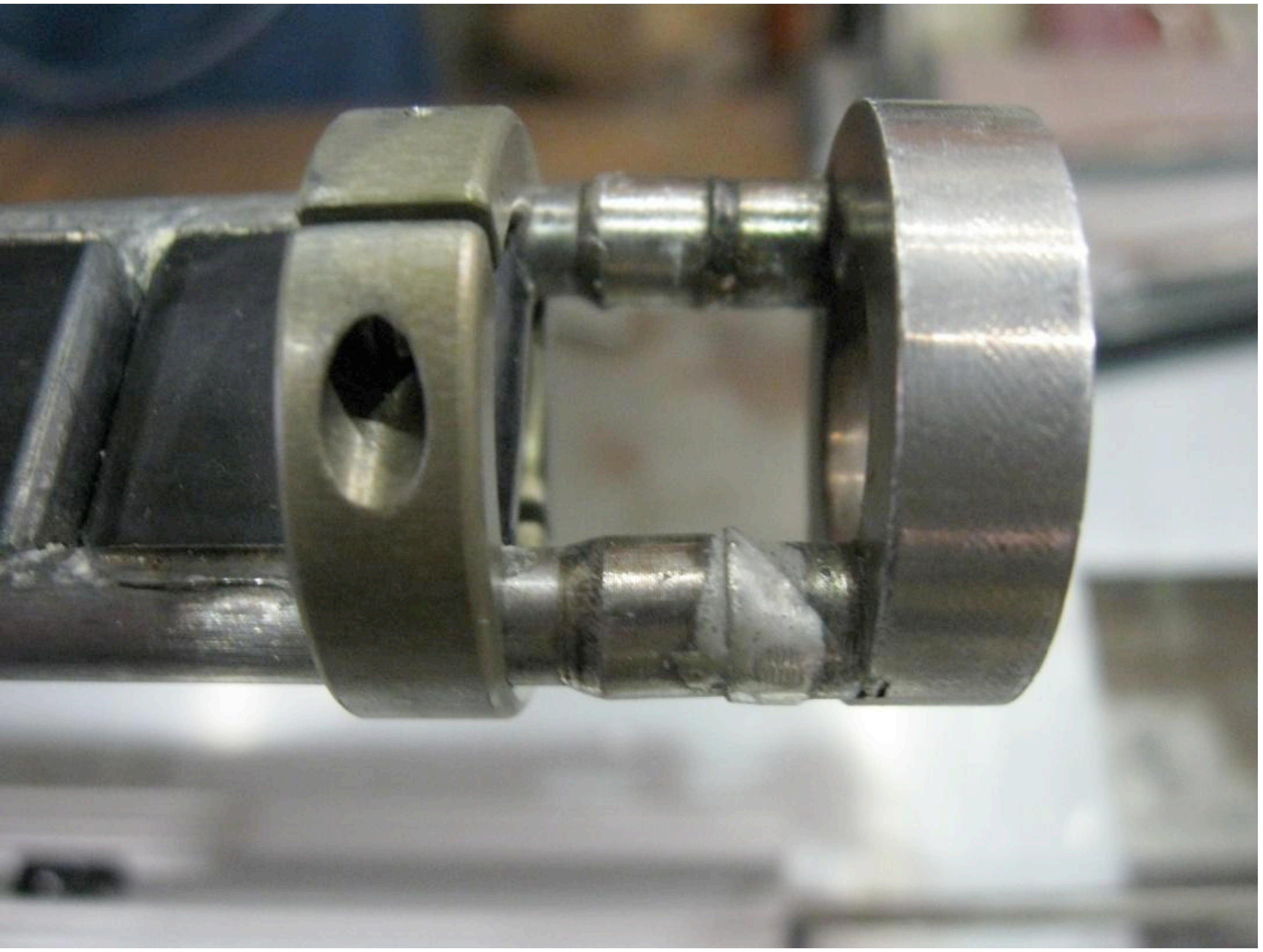
Summary of Target Issues

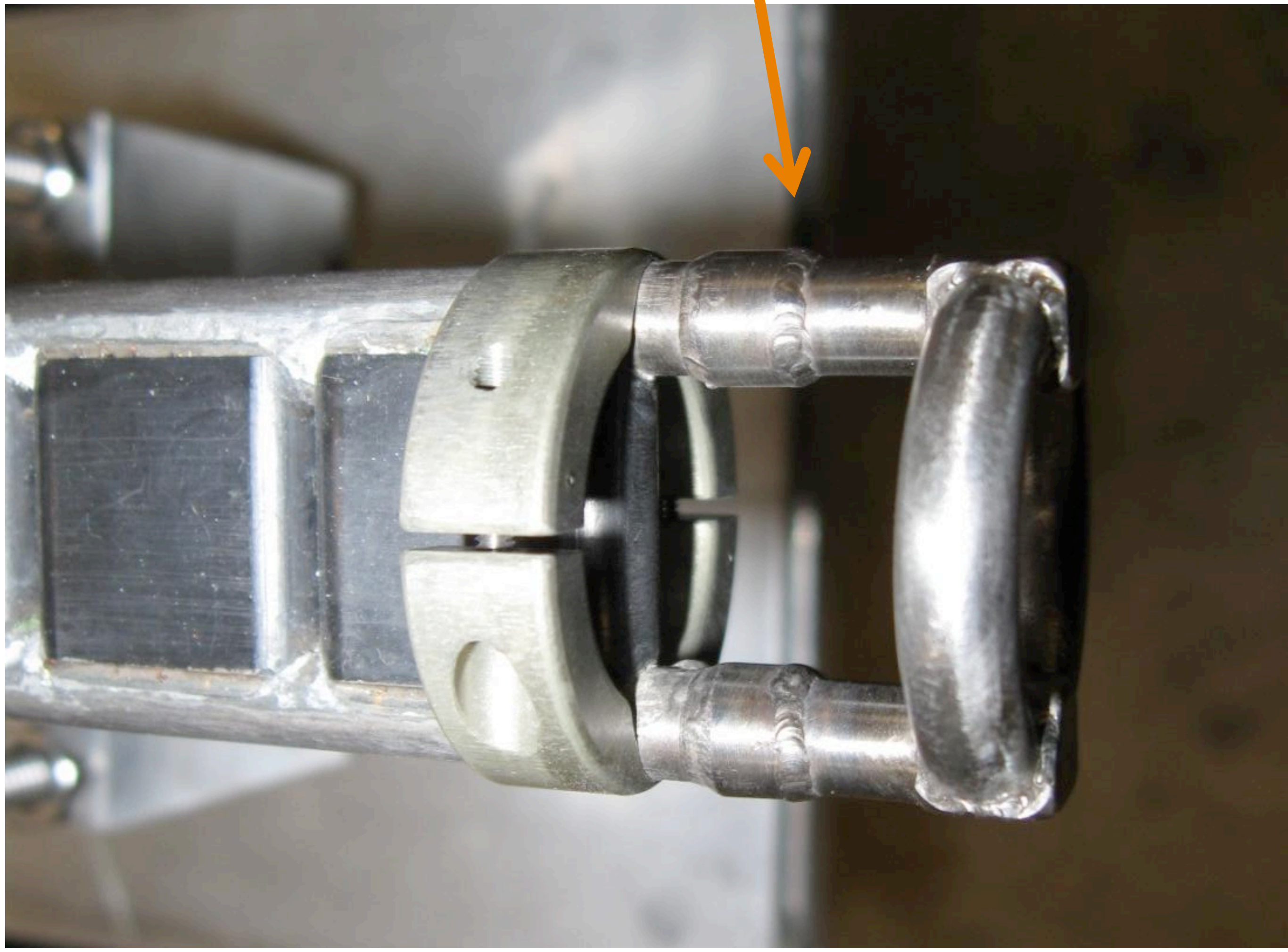
- 2 Failures of the water turnaround
  - Turn around redesigned at FNAL
  - Changing to from stainless to titanium cooling line
- 1 Water leak at the upstream end of target
  - Adding bellows
- RAL design analysis
- Two redesigned targets due this summer
- Developing technology for titanium water cooling lines

NT-06 reworked

Ream old weld of water-feed-through at base (not shown)
Wire EDM off old water-turn around (minimal vibration)
Clean up and make room for new connection tube (made special tool)
Micro-tig-weld new tip on
Re-weld water feed-through
Pressure leak test

new weld

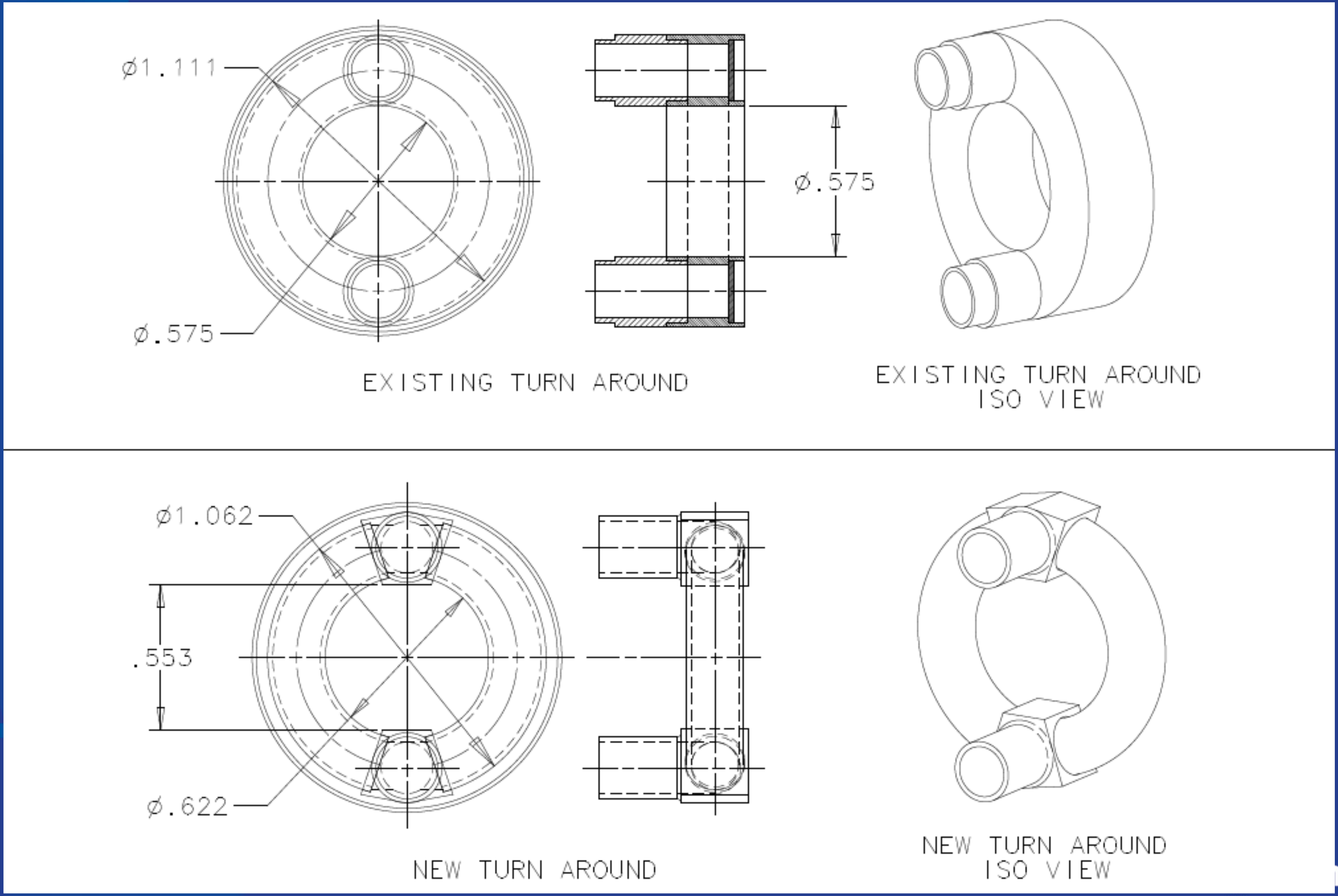




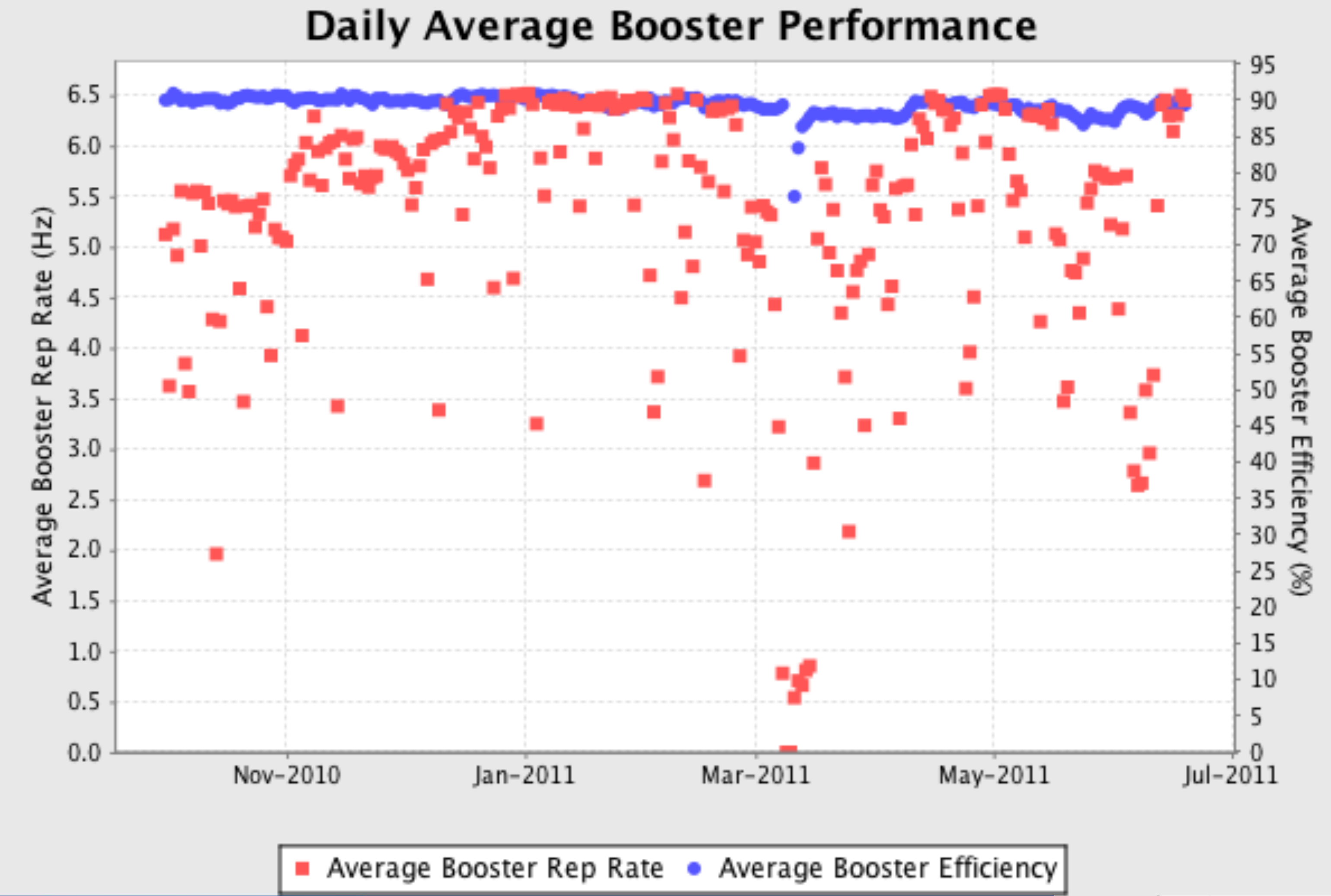
Before (note solder patch?)

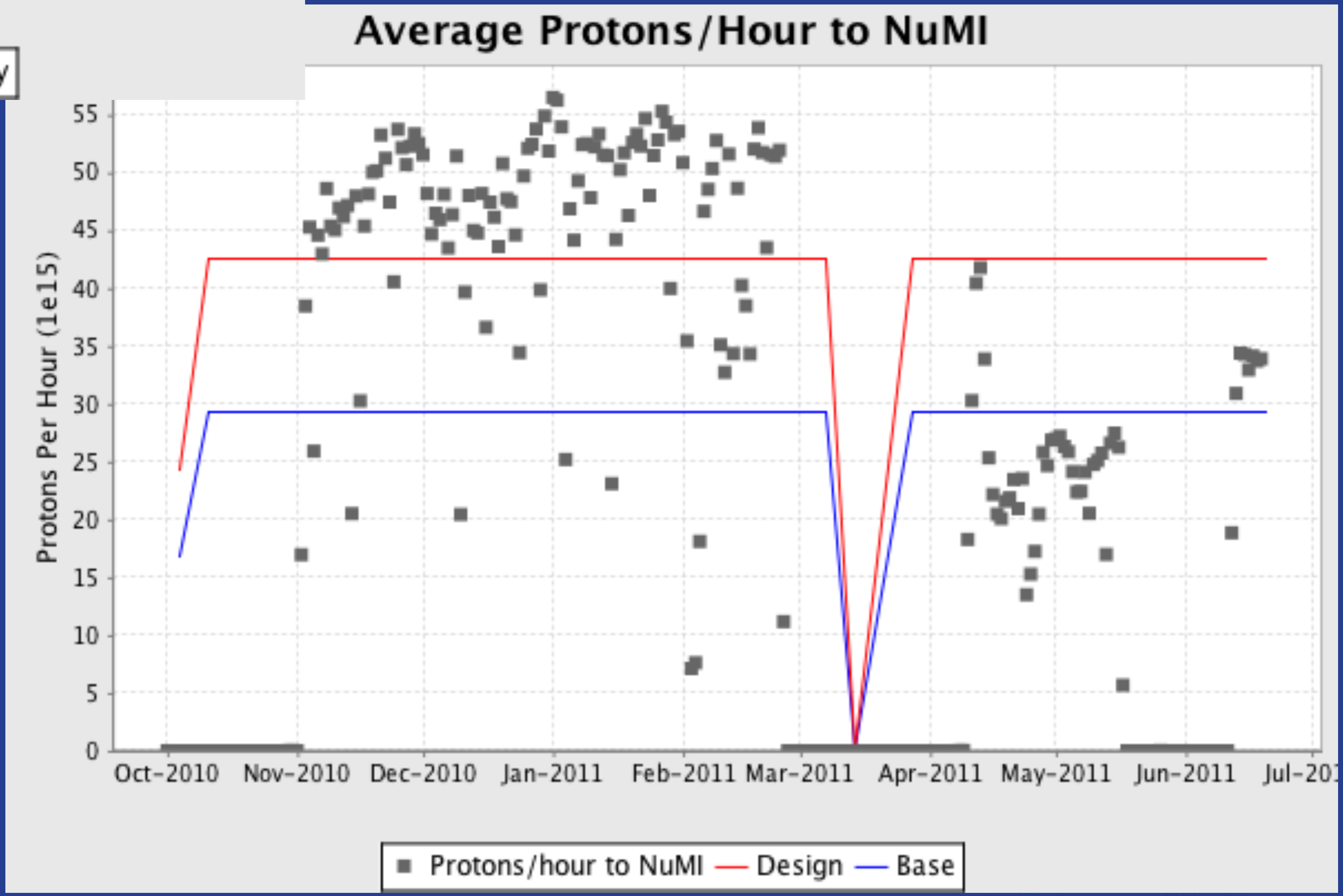
After

Turnaround Retro fit

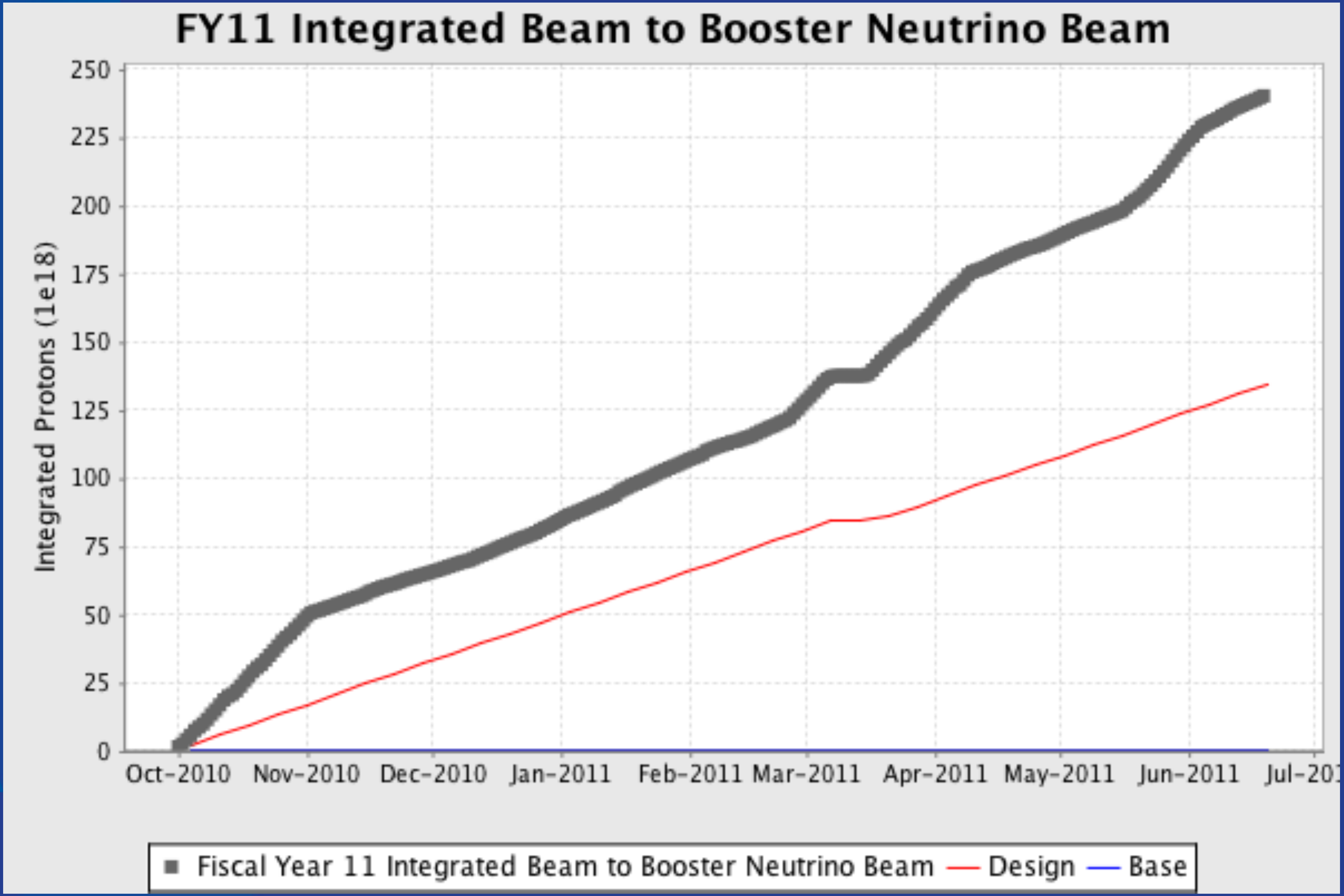


8-GeV Booster Performannce





8- GeV Neutrino Beam Performance



Proton Source Improvement Plan (PIP)

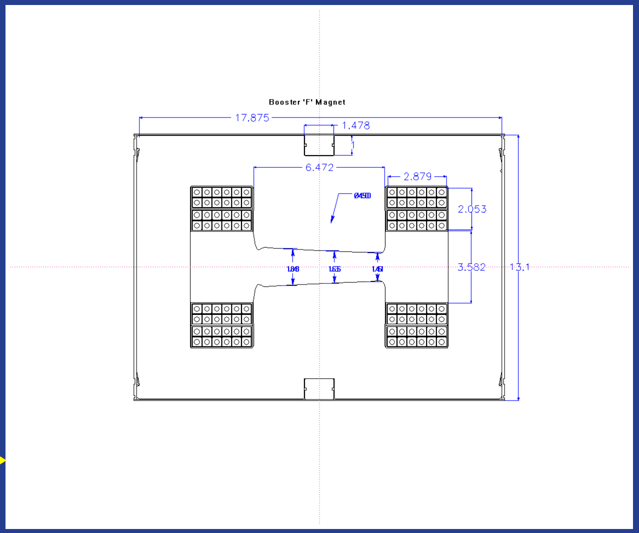
- Until the Project-X linear accelerator is operational, the entire domestic accelerator-based high-energy physics program is powered by the 40+ year old Proton Source
- Demands on the Proton Source continue to increase
- Experiments that have received Fermilab PAC approval or are in the DOE CD-process expect a factor of two increase of the current proton delivery rate within the coming decade

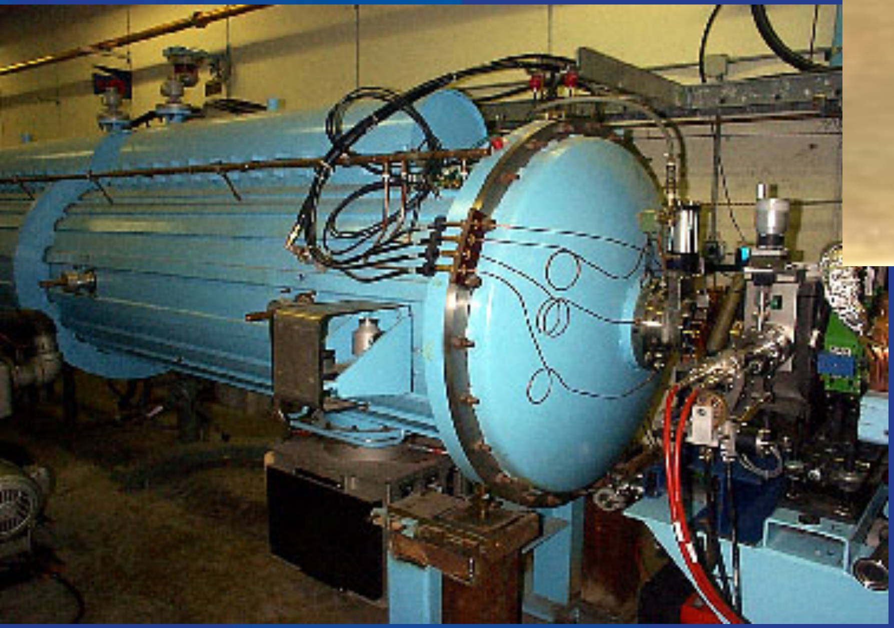
Proton Source Review – Basic Hardware

Cockcroft-Walton
H-

800 MHz Klystron
High Energy Linac

Booster
Gradient
Magnet





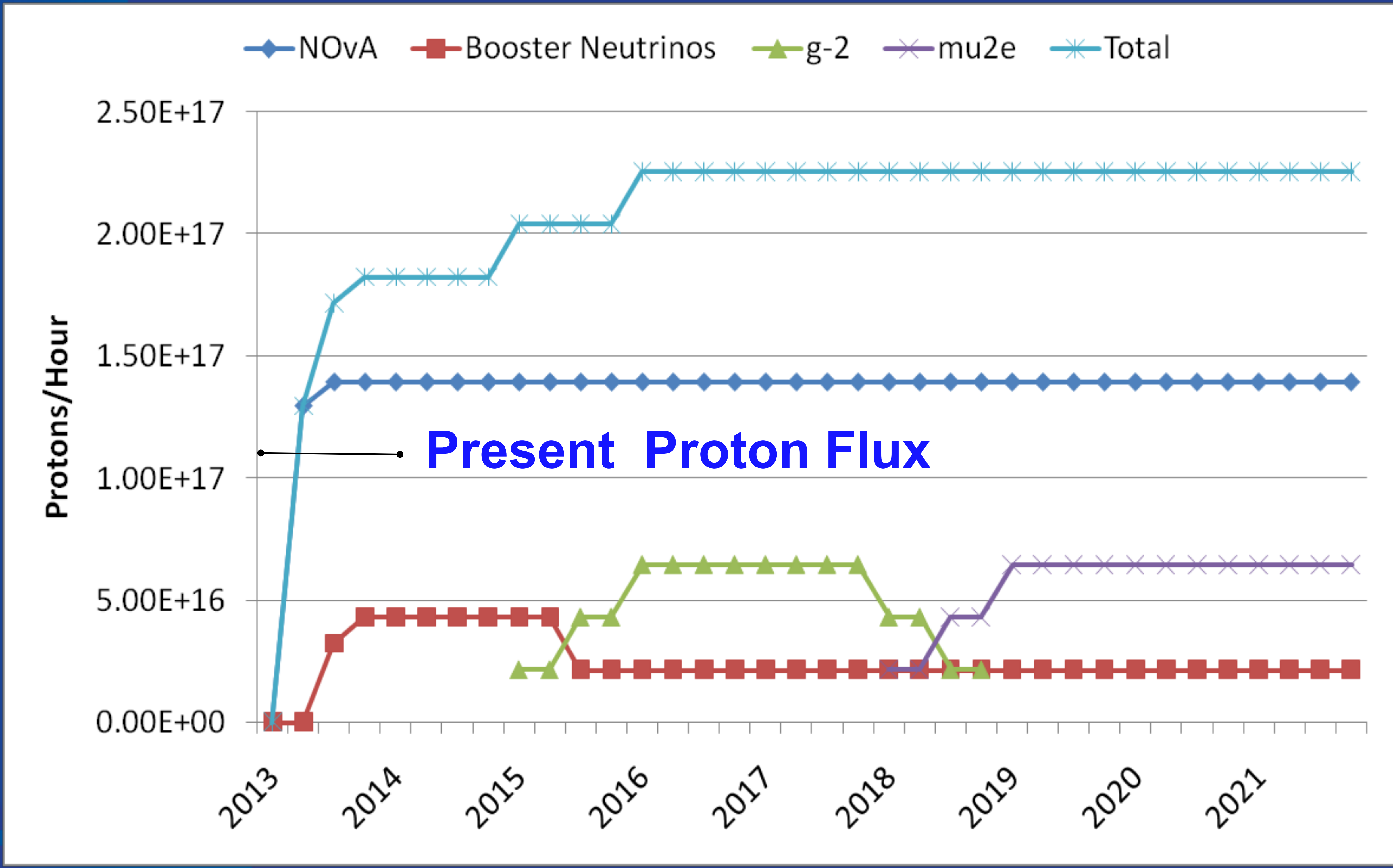
200 MHz Alvarez LE
Accelerating Cavity

Booster
RF
Cavity

PIP Goals

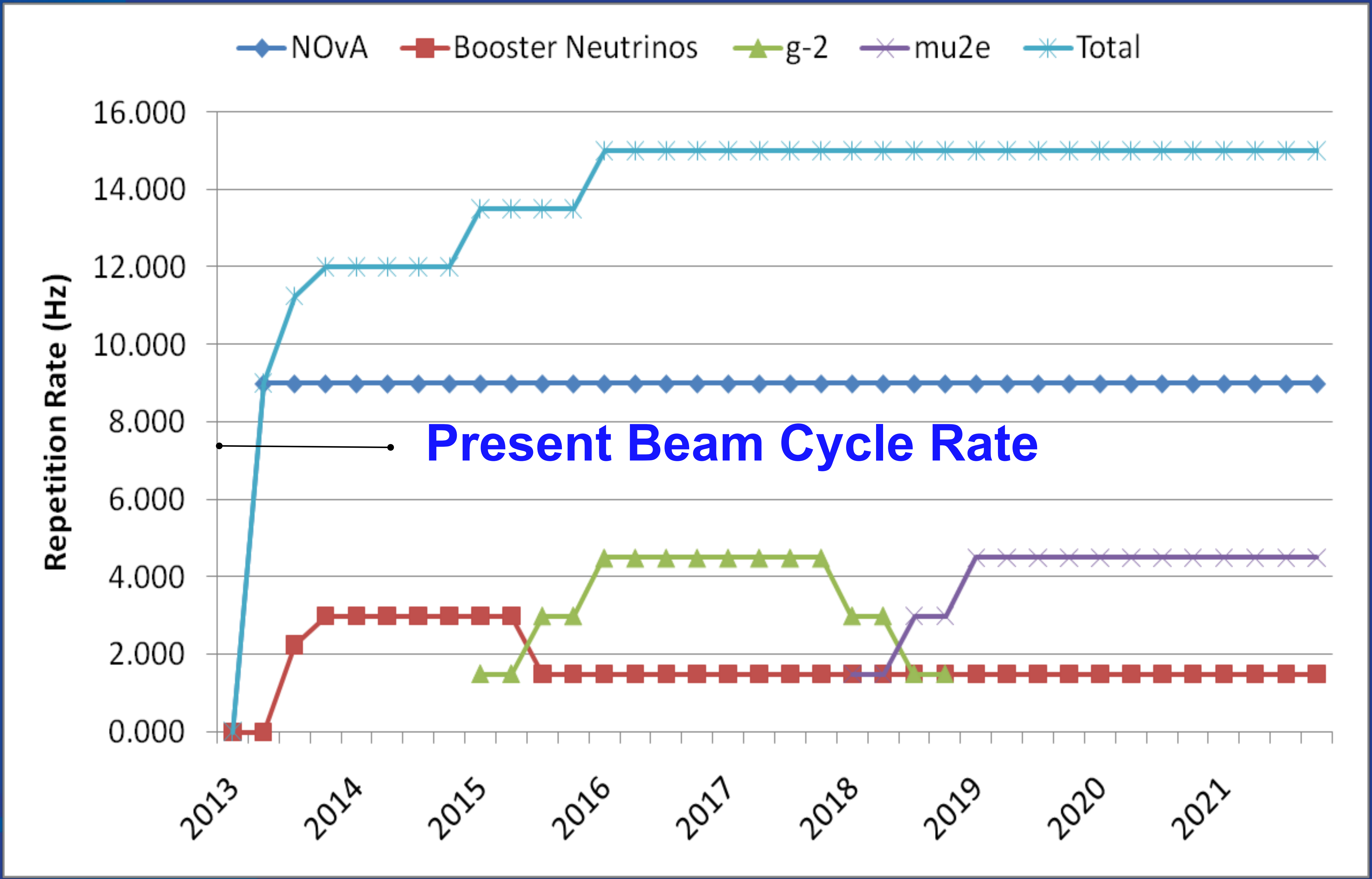
- Increase the beam repetition rate from the present ~7 Hz to 15 Hz
- Eliminate major reliability vulnerabilities and maintain reliability at present levels (>85%) at the full repetition rate
- Eliminate major obsolescence issues
- Increase the proton source throughput, with a *goal* of > 2E17 protons/hour
- Ensure a useful operating life of the proton source through at least 2025

Proton Source Improvement Plan (PIP)



Proton source throughput goals for the next decade.

Proton Source Improvement Plan (PIP)



Beam repetition rate goals through the next decade

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Proton Source Improvement Plan Scope – Major Items/Categories

- **The Cockcroft-Walton system**
- **Drift Tube Linac RF Power Systems**
- **Booster RF Solid State Program**
- **Booster RF Cavities, Tuners, Anode Supplies, and Bias Supplies**
- **Beam Instrumentation and Controls**
- **Linac and Booster Conventional Systems**
- **Vacuum system upgrades**
- **Booster Gradient Magnet Spares**

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Proton Improvement Plan: Items in Progress

- Replacing Cockroft-Walton with RFQ
  - RFQ will be delivered this summer and will be installed during the NOvA shutdown
- Booster Solid State Upgrade underway
  - 4 out of 19 stations installed and commissioned with two more installations scheduled for next month
  - Purchasing and assembling remaining stations
- Booster RF Cavity Upgrade
  - Refurbishing Tuners
- Utility upgrades for higher rep rate

Accelerator Upgrades for NOvA

- Increase power on ν target to 700 kW
  - Slip Stacking in Recycler
  - 1.33 second cycle in Main Injector
  - Target station upgrades
    - ν energy configuration
    - to handle increased power

NOvA ANU: Recycler

- Recycler Upgrades: from a pbar storage ring to a proton slip stacking ring
  - MI 10, MI 20, MI 30 — Decommission pbar cooling and transfer lines
  - 2 new transfer lines
    - Injection: Booster to RR — MI 8 and MI 10
    - Preserve Booster Neutrino Beam and MI capabilities
    - Extraction: Recycler to MI — MI 30
  - New fast kickers 12 vs 11 injected 57 nsec rise/fall
    - 5 different kicker systems
  - MI 10, MI 30, MI 40 — New magnets
    - New/modified designs PDS MLAW
    - Existing Designs PDD RQN
  - Refurbished Magnets ADCW

NOvA ANU: Recycler

- Recycler Upgrades:
  - MI 60 — 53 MHz RF for Capture and Slip Stacking
    - New cavities, under construction
  - Instrumentation Upgrades
    - everywhere — BPMs — cabling and electronics for 53 MHz
    - MI 10 and MI 30 — MultiWires — in transfer lines
    - MI 60 — DCCT — for intensity measurements

NOvA ANU: Main Injector

MI 60

- To handle faster ramp:
  - 2 “New” RF stations 18 -> 20
    - Cavities from existing MI spares
    - New modulators, ferrite bias supplies, power amplifiers
  - Power upgrades
    - New transformer for quad bus
    - Move Tevatron Anode Power supply for RF

NOvA ANU: NuMI

A1 line, MI50, NuMI line

- Transfer Line:
  - Magnet & PS upgrades: faster cycle time
  - Instrumentation & Diagnostics: intensity

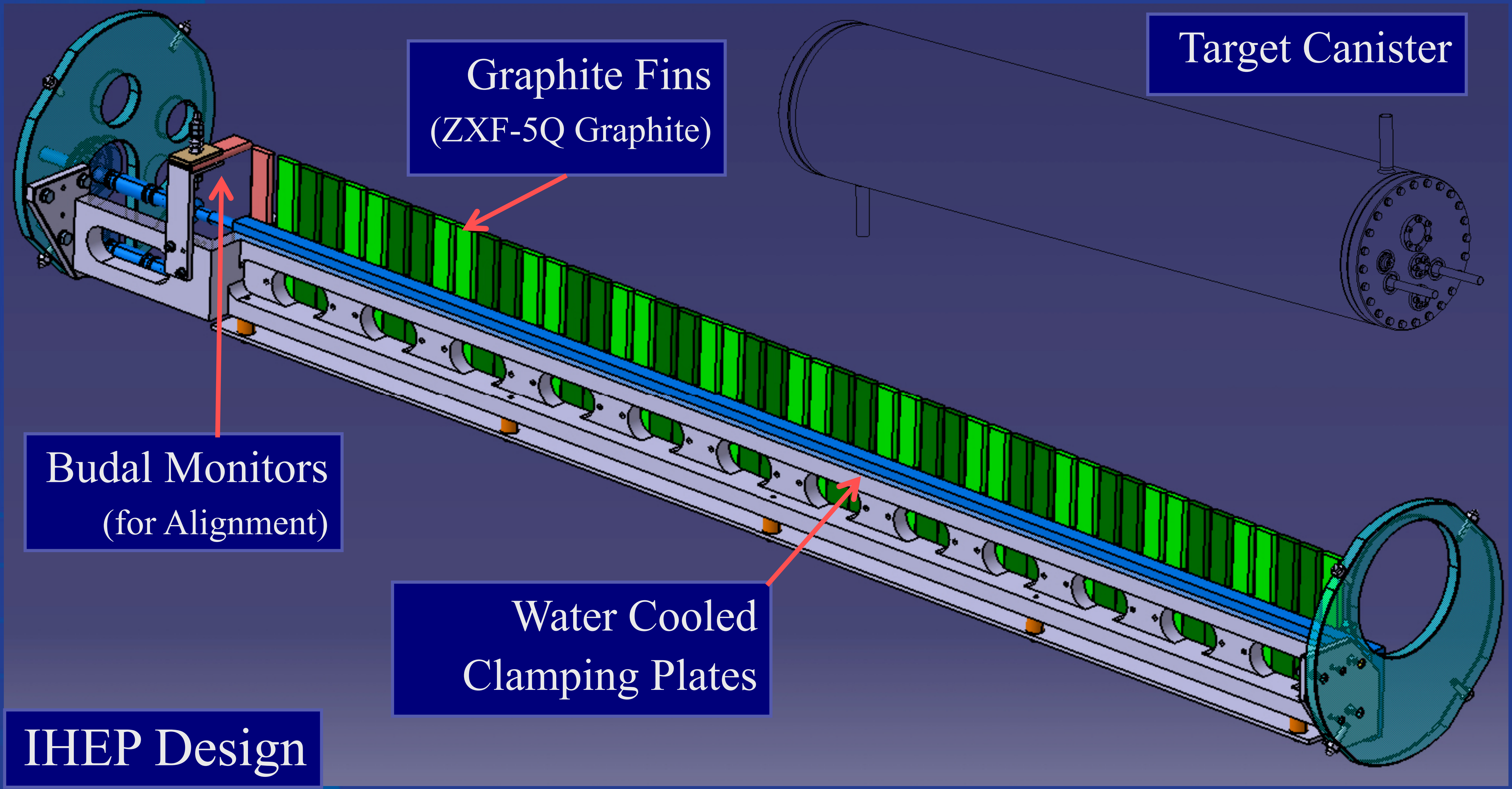
NuMI Target hall

- New Target Design Medium Energy position
  - No motion
  - Not constrained inside horn
  - Lessons learned from NuMI targets have been applied to design
  - IHEP design
  - IHEP & STFC/RAL construction

NuMI Target hall

- Relocate Horn 2
  - ~9 m downstream
  - Utility upgrades

NOvA ANU: Target



NOvA ANU: Shutdown

- Scheduled 11 month shutdown
  - Recycler and MI upgrades
  - NuMI Target Hall upgrades
  - 1 Mar 2012 – 1 Feb 2013
- Working on coordination since September 2010
  - Balancing of time, traffic, and tasks
    - Radiation and ALARA
      - MI 30 is hot
      - NuMI Target Hall is hot
    - Traffic: MI 60 is access point
    - Resources: people and equipment

Test Beam and SeaQuest

- Test beam runs ≤ 50% of time as needed
  - 5% impact on stacking
  - Adding second test beam in the meson area
- SeaQuest beam issues
  - Radiation Shielding– resolved
  - Old equipment and infrastructure– resolved
  - Leak in buried vacuum pipe– in process
    - Pipe is ~ 700 feet long and diameter varies 16 to 30 inches
    - Have run a camera through the pipe
    - Plan will be to insert a smaller diameter Pipe inside the existing pipe

Summary

- Collider running
  - Will meet performance goals on luminosity
  - End of Tevatron Studies in process
- Neutrino beams
  - Three target failures this year
  - NT01 installed and running
  - Waiting for two new targets to be delivered this summer
- Test beam also running as needed
- SeaQuest installation continues

Summary (Con't.)

- Proton Improvement Plan in Progress with RFQ, BSSU, and RF Cavity refurbishment
- Preparations underway for NOvA modifications to the Main Injector, Recycler, and Neutrino Target

Backup Slides

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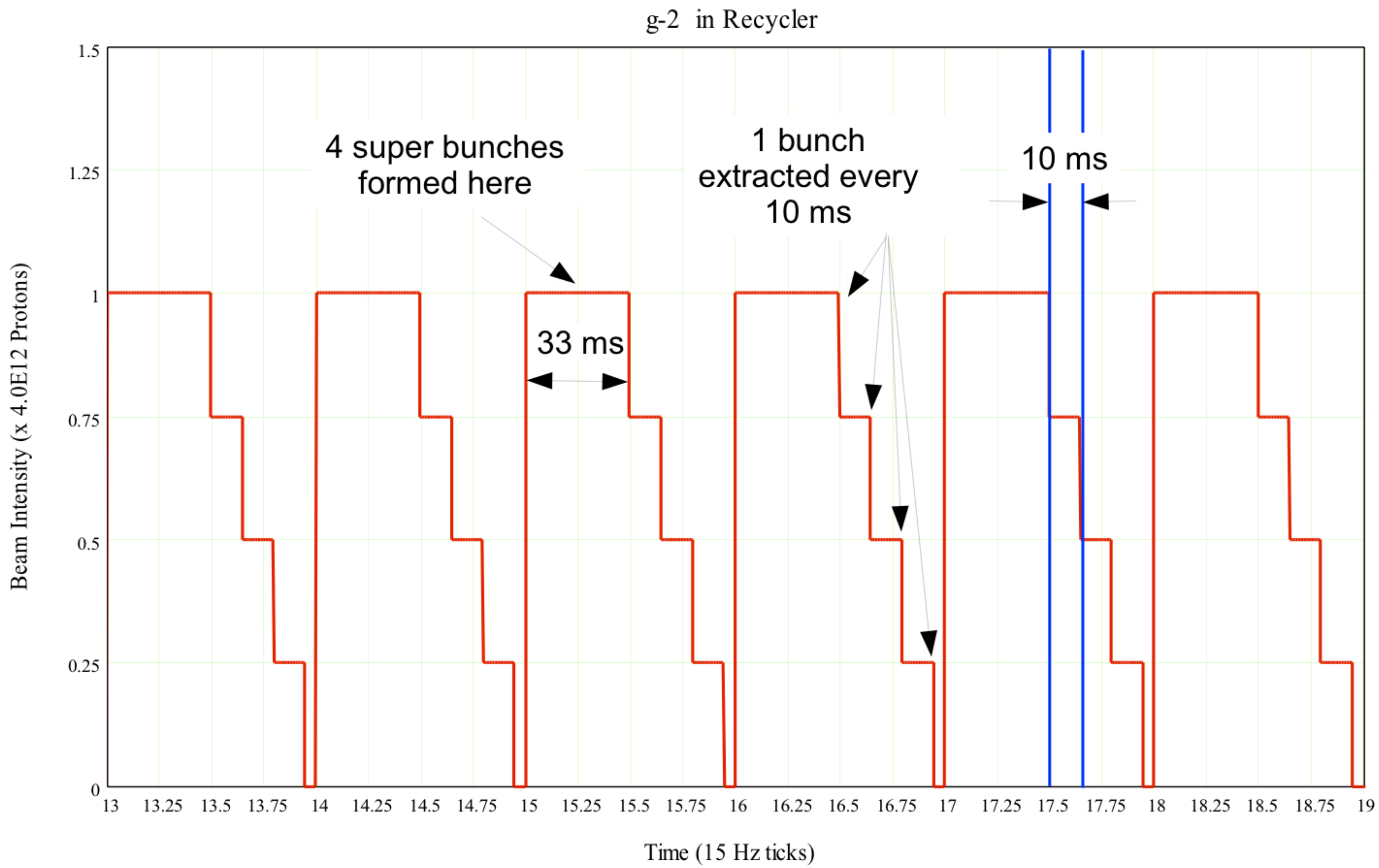
Zoom-In to g-2 Cycles



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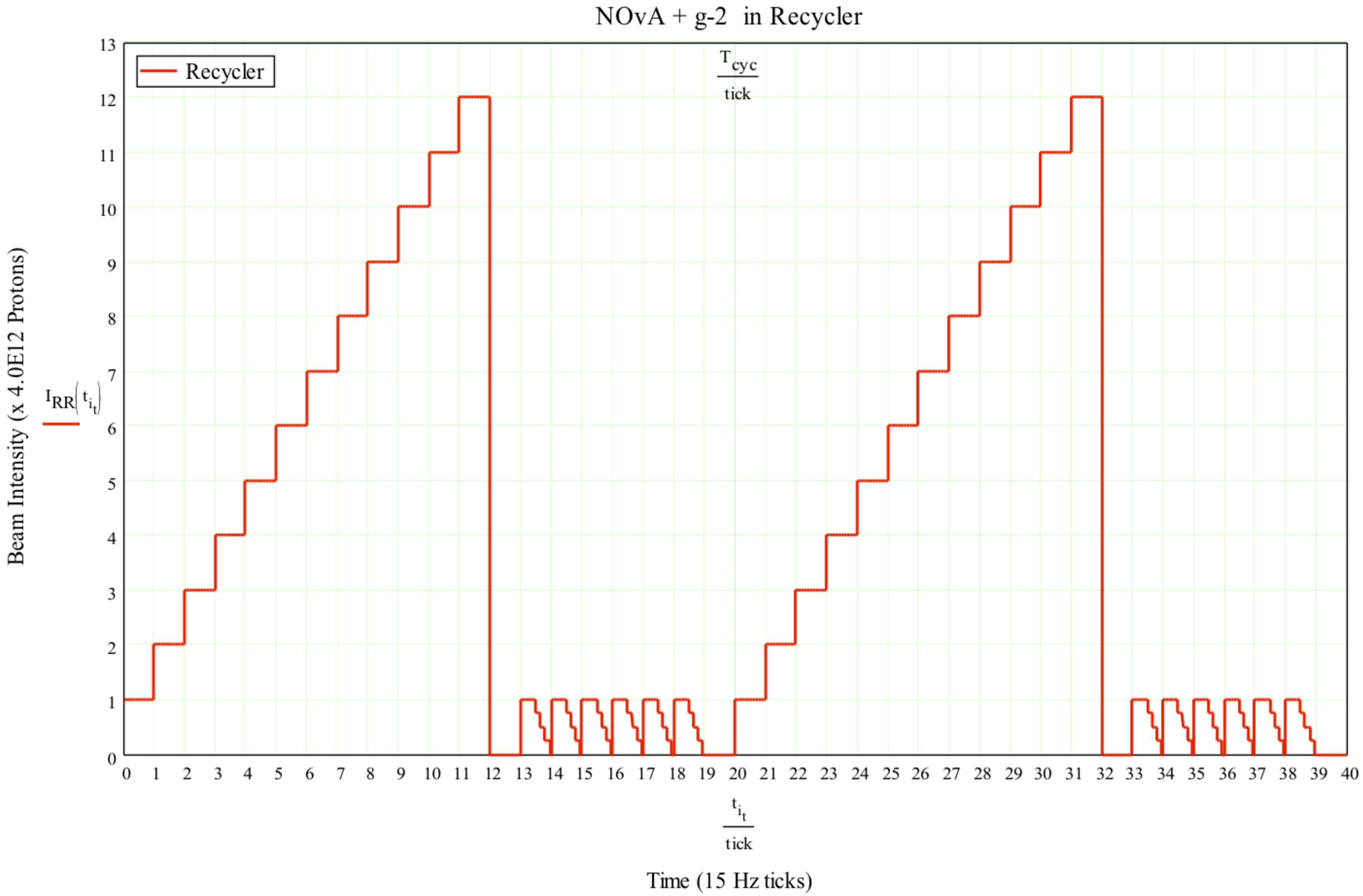
Timeline for NOvA + g-2



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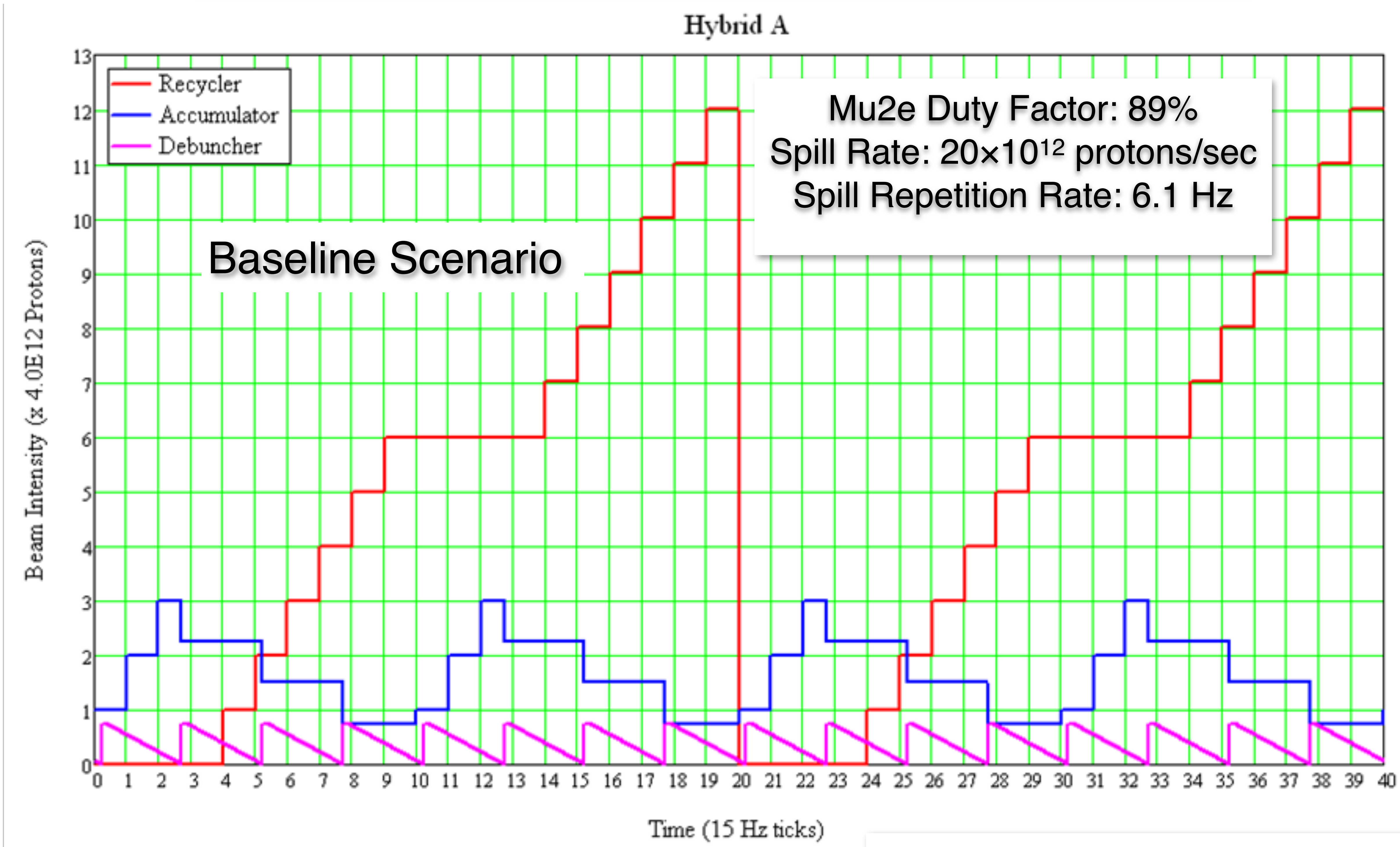
2011 DOE Goals

- Collider
  - 52 weeks scheduled
  - Design curve = 2700 pb-1
  - Subtract: 2 weeks for unscheduled downtime
  - Subtract : 6 weeks for possible end of run accelerator studies
  - Subtract: 15% to get to 90% confidence level
  - ⇒ Performance Metric: 2000 pb-1
- NuMI
  - 50 weeks scheduled
  - Design curve = 3.4E20
  - Base curve = 2.4E20
  - Take 2B+D weighted average to get 90% confidence
  - ⇒ Performance Metric: 2.7E20

Mu2e Accelerator Timeline



Hybrid A: 3 Booster Batches
Hybrid B: 2 Booster Batches

Proton Source Review

Pre-Acc/Linac

- A 400 MeV negative hydrogen ion accelerator comprising:

25 keV H-minus magnetron ion source

Two 750 keV electrostatic Cockcroft Walton accelerators

116 MeV, 201.25 MHz drift-tube (Alvarez) linac

805 MHz side-coupled cavity linac to 400 MeV

Booster

- 8 GeV, 15 Hz synchrotron with a 474 meter circumference .

Using multi-turn injection and a stripping foil, 400 Mev Beam is injected into the Booster from the Linac via the 400 MeV transport line.

Booster accelerates the beam from 400 MeV to 8 GeV in about 35 milliseconds.

Booster 8 GeV proton beam is extracted down the MI-8 line for the Main Injector or the 8 GeV neutrino experiments